Building Energy Efficiency for Massive market Uptake

Beem-Up Final reporting of monitoring results in all three sites

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BEEM-UP

Building Energy Efficiency for Massive market UPtake

Integrated Project

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Demonstration of Energy Efficiency through Retrofitting of Buildings

Deliverable D.3.8
Final reporting of monitoring results in all three sites

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Deliverable description

This document provides the final reporting of the monitoring results obtained in all the three demonstration sites of the BEEM-UP project. It is based on the general monitoring guidelines that have been developed for the BEEM-UP project in Deliverable 3.1 [1] and on the Measurement and Verification Protocol of the three sites of the project (Deliverable 3.2 [2]).

The document gives a comparison between the measurements performed within the three sites after refurbishment and the data collected during the baseline period. Therefore it provides energy savings values obtained thanks to the refurbishment process achieved in all three sites.

This report also delivers detailed information about the energy consumption with a granularity allowing evaluating the functioning of the housings and buildings.

Moreover a comprehensive analysis is conducted to explain the discrepancies observed between the measurements (real conditions) and the simulated data (predictions) as well as the global objectives of the project.

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EXECUTIVE SUMMARY

This document provides a detailed reporting of the monitoring results obtained in all the three demonstration sites of the BEEM-UP project.
The document focuses on the energy savings achieved and identifies and explain the discrepancies observed between the measurements of the real performances and the predictions.

The following table summarizes the energy savings results achieved in all three sites:

MONITORED SAVINGS (%)	Alingsås	Delft	Paris	Objectives of the BEEM-UP project
Heating savings	80*	45	60-65	75
Domestic hot water savings	16/8→mean value=12	50 to + 55 Average: -14	0/52**	45
Electricity savings	36/35→mean value=35	0	58	42 (lighting)

**After optimization of the system*
***Considering reduced heat losses in the DHW distribution circuit*

Table 1: Summary of savings results for all three sites

Alingsås:
Some pretty good results are obtained in Alingsås with energy savings that are in line with the objectives of the project. The use of domestic hot water, electricity and heating has decreased after refurbishment. The savings achieved for the heating demand (80%) comply with the objectives of the project. The savings achieved for the DHW (about 12%) is lower than the predictions and it is also largely lower than the objectives of the BEEM-UP project. The objective of 45% savings in energy for domestic hot water seemed to be too ambitious especially, as the consumptions are very much dependent on tenants´ behavior. The electricity consumption (sum of domestic and common consumptions) that includes lighting consumption shows a decrease of 35%. The discrepancy between this result and the objective of the project on lighting (42%) could be explained by tenants' habits also.
The small discrepancies observed between predictions and measurements concerning heating can be explained by indoor temperatures that are higher than the one used for the calculations. Therefore some energy savings opportunities are still identified in the Alingsås site. Nevertheless, the results of the measurements show that even if the used energy does not fully match the predicted performance, this renovated house uses 27% less energy than what is required for a newly built house in Sweden in terms of energy consumptions.

Delft:
The savings are expressed as actual achieved savings during a two year period after the renovation compared to the monitored reference situation and for the complete renovation package including the free selective measures. This excludes the subfloor insulation that was canceled as a measure that the users could select. The practical results are lower than calculated, due to discrepancies between the

general input parameter for the calculations and the household - and behavioral characteristics in the project. The energy saving percentage does not include the rebound effects. By correcting for more comfort enjoyed, the heating savings would be higher than 50%. The buildings do not have collective electricity driven services, and all electricity use is for private household use. However, this includes pump energy for the heating system and solar hot water circulation. There have been minor (negative) changes in electricity using functions, but the electricity use is rather constant. Overall, the energy consumption in the Delft project is 15% lower for gas (heating, hot water and cooking) than the Dutch average household and even 30% lower than the average electricity consumption.

Paris:

The use of general electricity and heating has decreased after refurbishment (60-65% savings for heating, 58% for general electricity). There is almost no saving observed for the DHW consumptions in the Paris site even if the BIOFLUIDES system is providing free energy for the hot water production. This is due to the large amount of energy lost in the DHW distribution circuit. Compared to the general objectives of the project, the results obtained for heating savings are a little bit lower than those expected. Nevertheless substantial savings are however achieved even if the results are preliminary (less than one year of monitoring). The results obtained for DHW are well below the objectives of the project but in this case, the configuration of the selected solution (BIOFLUIDES system for preheating + gas boilers providing additional heating and maintaining the DHW loop in temperature) may explain the poor results obtained. The detailed data collected thanks to the monitoring instrumentation highlights a large amount of heat losses in the DHW circuit.

Concerning the DHW, two kinds of energy are used for the production of DHW (gas plus electricity used for the BIOFLUIDES system). The gas boilers are used to raise the temperature up to 60°C but also to maintain the DHW circuit at the same temperature and this can explain the high gas consumptions measured in 2014. The consumption related to the latter can be highly affected by the distribution circuit that in the case of the Paris site is not as performant as intended.

As a general rule (all the following explanation is applicable for all three sites), the reasons for the differences between measurements and predictions can be the following:

- The air exchange rates before refurbishment were not measured (could be higher or lower than assumed) and this parameter can have a large influence on the calculated results in terms of heating consumptions particularly.
- The ICT savings were based only on assumptions (for the WP1 calculations, it was assumed they were of the order of 12-15%).
- The room temperatures before refurbishment could have been lower than calculated (in the case of Delft, for instance, only one room was really heated before refurbishment).
- The efficiency of old building services could not be calculated exactly, only assumptions can be made (no information was available about efficiency of old components: boiler, air change rates unsure, distribution losses).
- The consumption of warm water may differ from calculations considerably (before and after) especially, as the consumptions are very much dependent on tenants´ behavior.

- The rebound effect could also be a very impacting parameter that cannot be anticipated nor measured and therefore that is difficult to quantify or estimate (higher temperature after refurbishment, lower temperature than calculated before refurbishment (pre-bound effect)…).

Nomenclature

The following nomenclature is valid for Sweden.

Atemp -The tempered area of the building.
The area enclosed by the inside of the building envelope of all storeys including cellars and attics for temperature-controlled spaces, intended to be heated to more than 10 °C [3]. The area occupied by interior walls, openings for stairs, shafts, etc., are included. The area for garages, within residential buildings or other building premises other than garages, are not included.

The building's energy use
The energy which, in normal use during a reference year, needs to be supplied to a building (often referred to as "purchased energy") for heating, comfort cooling, hot tap water and the building's property energy. If underfloor heating, towel dryers or other devices for heating are installed, their energy use is also included.

The building's property energy – in this report referred to as common electricity
The part of the electrical energy used for building services necessary for the use of the building, where the electricity consuming unit is in, under or affixed to the exterior of the building. This includes permanently installed lighting of common spaces and utility rooms. It also includes energy used in heating cables, pumps, fans, motors, control and monitoring equipment and the like. Externally locally placed devices that supply the building, such as pumps and fans for free cooling, are also included. Appliances intended for use other than for the building, such as engine and compartment heaters for vehicles, battery chargers for external users, lighting in gardens and walkways, are not included.

Domestic energy – in this report referred to as domestic electricity
Electricity or other form of energy consumed for domestic purposes. Examples of this are electricity consumption for dishwashers, washing machines, dryers (also in shared laundry rooms), stoves, fridges, freezers, and other household appliances and lighting, computers, TVs and other consumer electronics and the like.

The building's specific energy use
The building's energy use divided by Atemp expressed in kWh/m2 and year. Domestic energy is not included. Neither is operational energy, used in addition to the building's basic operation adapted requirements, for heat, hot water and ventilation.

Common electricity
Electricity that is related to the needs of the building where the electricity using appliance is within, below or applied on the outside of building. This includes fixed lighting in public and operational areas. Also included is energy used in heating cables, pumps, fans, motors, control and monitoring equipment etc. Externally locally based device that supplies building, such as pumps and fans free cooling, are also included. Appliances intended for another use than for the building, such as engine and cab heaters for vehicles, battery charger for external users, lighting in gardens and walkways, are not included.

Hot water circulation
Hot water circulation is used to minimize the time to get domestic hot water in the tap. A small amount of water is constantly circulating even when there is no use of hot water.

Specific fan power (SFP)
The sum of power rating for all fans in the ventilation system divided by the maximum flow of either supply air or extract air, kW/(m^3/s).

Hot water circulation losses
They concern the heat losses from the pipes that are directly connected to the circulation of water.

Mechanical supply and exhaust air with heat exchange -
A type of ventilation system where both supply and exhaust air is driven by fans. The supply air is heat exchanged with the exhaust air.

Natural ventilation -
Ventilation where no fans are used and the air is supplied through leakages in the building envelope and windows.

Chapter 1 Final reporting of monitoring results for the site of Alingsås

1.1 Main characteristics of the pilot site and reminder on the methodology used

1.1.1 Main characteristics of the pilot site and reminder on the refurbishment

The BEEM-UP demonstration in Alingsås, Sweden, is a complete refurbishment of 144 dwellings distributed over 8 houses. The houses, built in the 1970s, have been stripped down to the concrete skeleton and been refurbished using passive house techniques. The houses are extremely well insulated and need next to no additional heating.

Key indicators of the pilot site	Value for the Swedish pilot site
Location	Alingsås (Sweden)
Year of construction	1971-1973
Surface retrofitted	14,860 m² gross living area for the 8 blocks involved in the BEEM-UP project (1613m² for the Building H)
Number of dwellings	144
Owner/partner	Alingsåshem AB
Level of intervention	Deep renovation (tenants evacuated during retrofitting)
Total investment	€ 22,25 millions

Table 2: Key indicators related to the Swedish pilot site

Within the BEEM-UP project, one house has been selected for monitoring. The house holds 18 apartments on 3 floors and has a south facing façade. The size of the apartments varies from 1 to 4 rooms + kitchen per dwelling. The house is called “building H” within the BEEM-UP project. The monitoring of the building is done both on building level as well as more in detail for four of the apartments (see deliverable D 3.3, [4]). This building has also a shared laundry room. The 4 apartments have been chosen to be as representative of all the dwellings as possible in terms of orientation, stairwell and typology. Therefore it is assumed that this sample is representing well enough the behavior of the other apartments.
The following pictures show the renovated buildings as well as the House H during the renovation process in Alingsås.

a)

b)

c) 

Figure 1: Pilot site in Alingsås

a) A renovated building in front of the photo, building that has not yet been renovated in the back.
b) House H during renovation.

c) Facades and roofs of buildings B, C, F, G and H as seen clockwise

The interventions for the site of Alingsås through the implementation of Passive House standards are summarized in the table below.

Envelope	Walls: Previous wall is replaced by new wall with several layers of insulation and slotted steel studs. In total 440 mm insulation. Basement: 100 mm expanded polystyrene extends 1 meter below ground level. 100 mm drainage panel downwards to ground floor. Roof: 400 mm new mineral wool insulation.
Windows	New triple-glazed cryptone filled low-emitting windows (U_{window} 0.85 W/m²/K)
Heating (source and distribution)	District heating (bio fuelled), heat recovery from outlet air Airborne distribution with waterborne heat supply to air heaters, controlled per flat.
Domestic hot water	Central system, district heating as before. Reducing taps.
Ventilation system	Central system, mechanical supply and exhaust system with heat recovery Single unit serves entire building.
ICT – energy management (incl. smart meters)	Electricity is measured individually; hot water is monitored remotely for each flat; heating is measured for each building. Individual billing and feedback is introduced.
Lighting	Low energy fittings. Low energy or halogen lighting and LED lighting in staircases.
Renewable Energy Source	District heating is renewable to 98%.
Other energy saving	The tenants receive energy-saving tips

Table 3: Improvement measures performed in the site of Alingsås

The techniques are described thoroughly in the deliverables from WP 2. For better understanding of the results, the reader is in this deliverable reminded of how the heating and ventilation system is designed. The heating and ventilation are closely linked together. Heat is supplied through the supply air. The exhaust air is heat exchanged with the supply air if there is a heating demand. If there is no heating demand the heat exchanger is not in use. The key for a low use of energy is a well-functioning heat exchanger.
The following graph describes the heating and ventilation system used in Brogården.

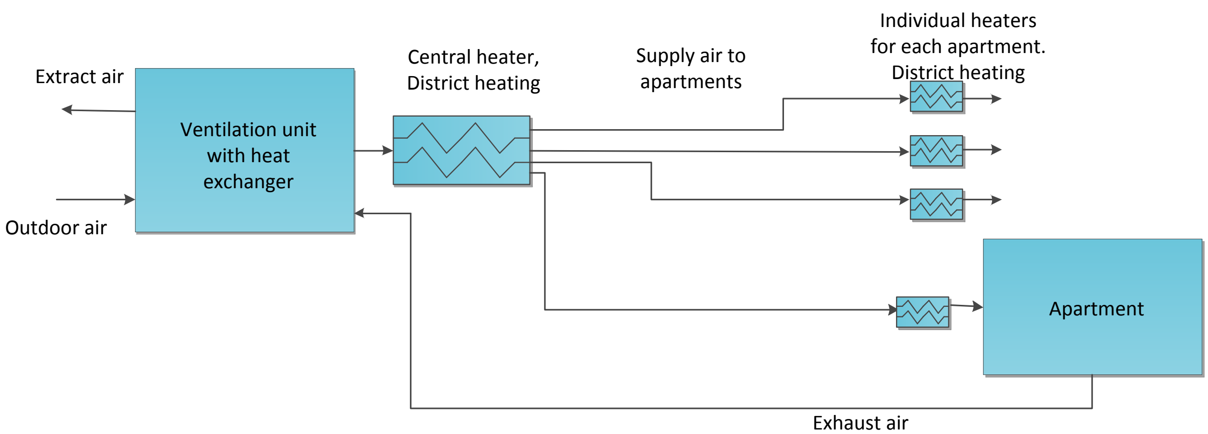


Figure 2: Reminder of the heating and ventilation system in Brogården.

Figure 3 shows the general timeline of the refurbishment performed in Alingsås. According to this timeline, the baseline period is considered from the beginning of 2007 till the end of 2008 and the reporting period is considered from the beginning of 2013 till the end of the BEEM-UP project.

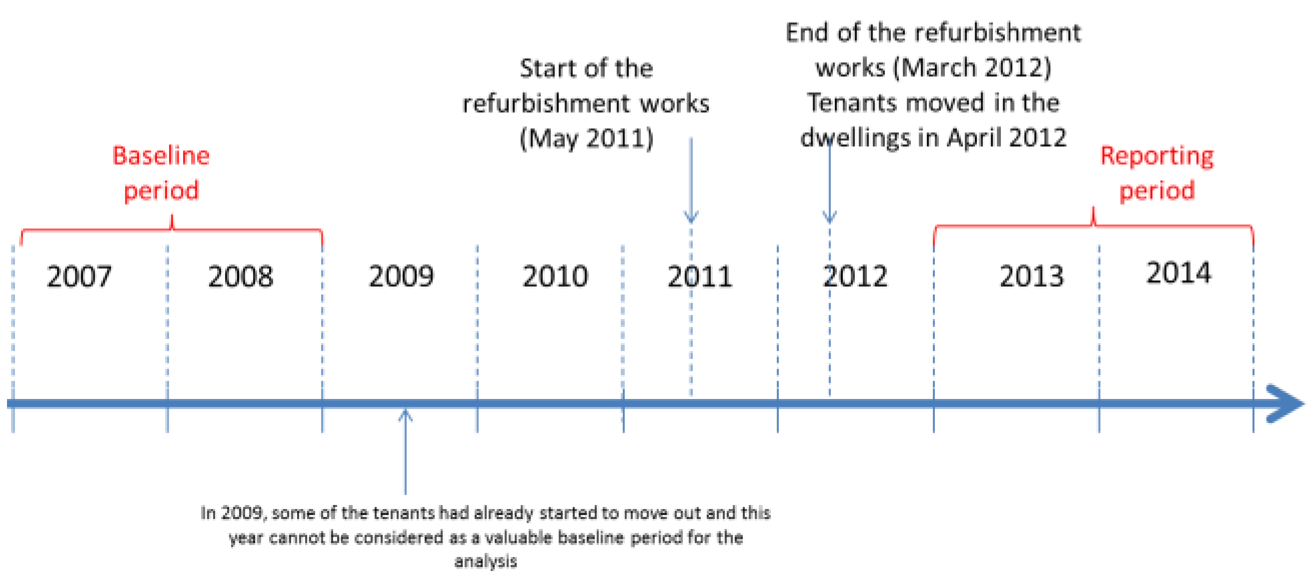


Figure 3: General Timeline of the measures performed in Alingsås (building H)

In Alingsås, district heating is used for domestic hot water and additional heating. The tenants are charged for the hot water but not for the heating. Monitoring is done with existing meters installed by the local energy company and complementary meters that were installed to get more information for the BEEM-UP project (see deliverable D3.3 [4]).

1.1.2 Data adjustment

1.1.2.1 Adjustment of the used energy before refurbishment

For Alingsås, adjustments are performed on heating consumptions in spring, summer and autumn with SMHI Degree Days[1].
During spring, summer and autumn, the solar irradiation has particular importance and therefore degree days are only calculated when the average daily temperature falls below certain values.
During the spring, summer and autumn, insulation has also particular importance. Degree days are calculated only when the daily mean temperature falls below the following values called "heating limits" which can be seen in Table 4. During winter there is no limit to the daily mean temperature.

	Heating limits
April	+12 °C
May-July	+10 °C
August	+11 °C
September	+12 °C
October	+13 °C

Table 4: Heating limits defined for spring, summer and autumn according to the Swedish metrological and hydrological institute.

The monthly degree days are always calculated as the sum of all daily average host differentials with +17 degrees. Summation is done only with the day which has an average daily temperature falling below the heating limit for the month.

1.1.2.2 Adjustment of the used energy after refurbishment

Since Brogården is a low energy building (according to the Passive House standards) after renovation, ordinary adjustment with HDD (Heating Degree Days) cannot be used as it is for the period before renovation.
The adjustment of the energy use after refurbishment should be made with a different method than the one used before renovation. This adjustment is only possible based on energy performance during a whole year.
A degree day is a measure of relative heating energy required by buildings. It's calculated as the difference between the average daily temperature and the balance point temperature. When the average daily temperature is below the balance point, the result is heating degree days. The balance point temperature is the average daily outside temperature at which a building maintains a comfortable indoor temperature without heating or cooling. At this outside temperature, the indoor heat gains (due to people, lighting, equipment, etc) "balance" with heat losses through windows, walls, roof and ventilation. For a very well insulated building with efficient ventilation and heat recovery systems, like the buildings retrofitted in Brogården, the balance point is considerably much lower than in an older

[1] SMHI – Swedish meteorological and hydrological institute

poorly insulated building with no ventilation nor heat recovery, e.g. 12°C instead of 17°C. Hence, when calculating the degree day correction for the retrofitted buildings in Brogården a different balance point shall be used.

The balance temperature has to be calculated with information about the energy used for heating and the outdoor temperature during a whole year. Therefore it is necessary to have an entire year of measurements before doing any adjustment of the energy performance.

1.1.2.3 Presentation of the results as energy per square meter

The energy performance of a building has to be presented as energy per square meter (A_{temp}) according to the Swedish National Board of Housing, Building and Planning. The energy performance is therefore presented this way so that the results can be compared to building regulation in Sweden.
Therefore, all energy data is presented as energy per square meter of floor area. The floor area used is the air conditioned net floor area. The definition of the air conditioned floor area is commonly used in Sweden, especially when it comes to determine the energy performance of a building.
The energy is presented as energy per square meter to be able to compare energy performance before and after refurbishment since the floor area has increased during the refurbishment. The increased area makes it impossible to compare the sum of the energy consumption before and after.
A_{temp} is defined as the sum of interior area for each floor, attic floor and basement that is heated to over 10 °C.
Table 5 shows the A_{temp} values to be considered for the two periods of analysis.

PERIOD	A_{temp} (m^2)
Baseline period	1613
Reporting period	1688

Table 5: A_{temp} values considered for the periods before and after refurbishment

1.2 Data available

The data available for the two periods (before and after refurbishment) are synthetized in the two tables below.

1.2.1 Baseline period

	Baseline period (before refurbishment)			
Available data	**Data available at dwelling level/Building level**	**Acquisition frequency**	**Provider of the data**	**Period of measurement**
Heating consumption	Data available for the group of 8 buildings (not available at the building H level)	Monthly	Local energy company	2007-2008
Electricity consumption	Data available at building H level	Monthly	Local energy company	2007-2008
DHW consumption	Data available for the group of 8 buildings (not available at the Building H level). The DHW is calculated as a standard value since there is only one meter that monitors both heating and DHW	Monthly	Local energy company	2007-2008
Indoor environmental conditions (temperature, RH, CO_2 concentration)	No information available	--	--	--
Ventilation consumption	No information available (natural ventilation)	--	--	--
Outdoor environmental conditions	Number of heating degree days compared to a normal year	Monthly	SMHI (Swedish Meteorological and Hydrological Institute)	2007-2008

1.2.2 Reporting period

	Reporting period (after refurbishment)			
Available data	**Data available at dwelling level/Building level**	**Acquisition frequency**	**Provider of the data**	**Period of measurement**
Heating consumption	Data available at building H level	Monthly	Local energy company	2013-01-01 → End of the project
Electricity consumption (common and domestic)	Common electricity: data available at building H level Domestic electricity: 18 dwellings (reference no. apartment 1-18)	Monthly	Local energy company	2013-01-01 → End of the project
DHW consumption	Data available for 18 dwellings (reference no. apartment 1-18).	Monthly	Local energy company	2013-01-01 → End of the project
Indoor environmental conditions (temperature, RH, CO_2 concentration)	Temperatures: 4 apartments (ref. apartments 1, 8, 13, 17) RH: ref. apartment 1, 3, 8 CO_2: 1 apartment (ref. apartment 1)	Monthly	SP	2013-01-01 → End of the project
Ventilation consumption	Data available at building H level	Monthly	SP	2013-01-01 → End of the project
Outdoor environmental conditions	Building H level	Monthly	SP	2013-01-01 → End of the project
Heat losses from domestic hot water circulation system	Data available for the group of 8 buildings (not available at the building H level)	Monthly	SP	2013-01-01 → End of the project

Table 6: Data available for the baseline and the reporting periods for Alingsås site

1.3 Analysis of final results

The analysis of the results in the Swedish site in Brogården has been conducted according to the three following approaches:

- Comparison of energy use before and after refurbishment to evaluate the energy savings achieved and compare them to the overall objectives of the BEEM-UP project,
- Comparison of energy use before and after refurbishment compared to the predicated performances of the building performed within WP1 of the BEEM-UP project,
- Comparison of the results with Swedish regulation and the predicted performance calculated by the building constructor (Skanska).

The results are presented using different time scale: at first the results are presented at a yearly level either as a sum or mean value. This enables the global savings calculation and the comparison to the calculations and overall objectives of the project.
Some results are presented in a more detailed way to be able to distinguish differences in behavior of the tenants or the regulation of the heating and ventilation system (daily or monthly analysis).

N.B.: Privacy considerations
With respect to the tenants living in the monitored building, all apartments' numbers have been changed so that it is not possible to link the results to a specific apartment or individual.

1.3.1 Outdoor climate and selection of representative weeks

The outdoor temperature and relative humidity were measured on the north side of the building, thus avoiding influence of solar irradiation.
Information about the solar irradiation was collected from SMHI.
According to the figures provided in Table 7, 2014 was somewhat warmer than a normal year. The summer of 2014 was extremely warm with temperatures around 30 °C for several weeks which is very unusual in Sweden. The following autumn was also very mild resulting in a mean outdoor temperature much higher than for a normal year.
The relative humidity is presented later in the chapter about the indoor climate.

	Normal year	Dec 2012-Nov 2013	Dec 2013-Nov 2014
Mean outdoor temperature (°C)	7,0*	7,9**	11.5**

**According to SMHI (Swedish Meteorological and Hydrological Institute)*
***Measured temperatures*

Table 7: Outdoor temperature measured on site

Some representative weeks that should be looked more closely have been selected by looking at data from the Swedish institute of metrology and hydrology (SMHI). For each season, a week with as normal outdoor temperatures as possible has been selected for a more detailed analysis. Weeks that coincide

with national holidays, summer breaks etc. have been deliberately left out so that, as far as possible, normal daily life is analyzed in the following section.
The following weeks (Table 8) have been chosen as representative weeks for the years of 2013 and 2014. A specific analysis has been performed for these weeks.

Season/year	2013	2014
Winter	10-17 January	10-17 January
Spring	1-7 April	1-7 April
Summer	1-7 June	1-7 June
Autumn	11-18 October	11-18 October

Table 8: Weeks with normal outdoor temperatures in Alingsås during 2013 and 2014.

1.3.2 Heating

When the first results of the monitoring of heating was analyzed in autumn 2013 it could be seen that the use of heating was much higher than what the predicted performance indicated: 38 kWh/m^2.year instead of the predicted 14 kWh/m^2.year (HDD adjusted values).
Table 9 gives the use of heating measured in the building for the baseline and the reporting periods for the whole years 2007-2008, 2013 and 2014.
As highlighted in Table 9, unnecessary use of heating has been observed during the summer months of 2013, when the temperatures are so high that even a "normal" Swedish house heated with district heating has the heating turned off. This can be concluded even if the values are unadjusted since a low energy house should not have a need for heating at all during the summer periods.

Heating			
	Baseline	Reporting period 1 Dec 2012- Nov 2013	Reporting period 2 Dec 2013- Nov 2014
	Adjusted values	Not adjusted values	Not adjusted values
	kWh/m² (Atemp)	kWh/m² (Atemp)	kWh/m² (Atemp)
December	19.0	6.0	3.0
January	18.9	5.7	4.7
February	16.7	5.1	2.9
March	16.3	5	2.5
April	12.5	3.4	1.4
May	12.3	1.6	0.6
June	9.8	0.7	0.0
July	3.4	0.3	0.0
August	2.4	0.5	0.0
September	7.5	1.5	0.0
October	10	3	0.6
November	13.1	2.7	2.6
Total use (kWh/m²/year)	**141.8**	**35.4**	**18.4**

Table 9: Use of district heating for the baseline period and the year of 2013.

To understand the reasons for this, the performance of the building has been analysed in detail.
The predicted performance is based on the assumption that no district heating is used for heating during spring, summer and autumn. But as can be seen in Figure 4, there has been a heating demand even in June 2013 when outdoor temperature has been high.

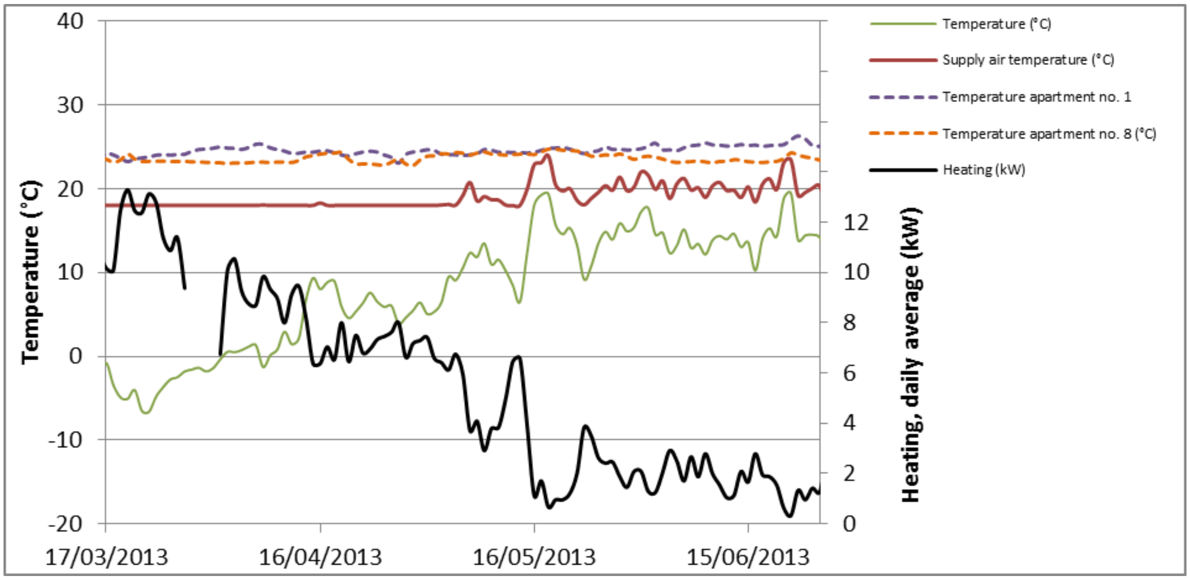


Figure 4: Use of heating during spring 2013 in the Brogården Building.

To understand why there is a heating demand also during spring and summer a closer look was taken at the ventilation system.
The supply air has a set-point of 18 °C. During summer nights the outdoor temperature falls below 18 °C forcing the heating system to start. Since the days are warm there should be a lot of energy stored in the building and the added heat is probably unnecessary (due to the fact that the building have near zero energy losses through the envelope…). A better regulation of the heating and ventilation system could probably avoid this unnecessary use of heat.
In Figure 5, a closer look is taken on the regulation of the recovery system. As can be seen if there is a heating demand both the district and the heat exchanger starts to add heat to the system. However the efficiency of the heat recovery is only around 20%. A well-functioning system would only use recovered heat with a higher efficiency. The same problem occurs during the winter months as well. Instead of increasing the heat recovery the heating is increased. Thus giving a higher need for energy for heating than expected since the calculations are done based on an efficiency of 85%.

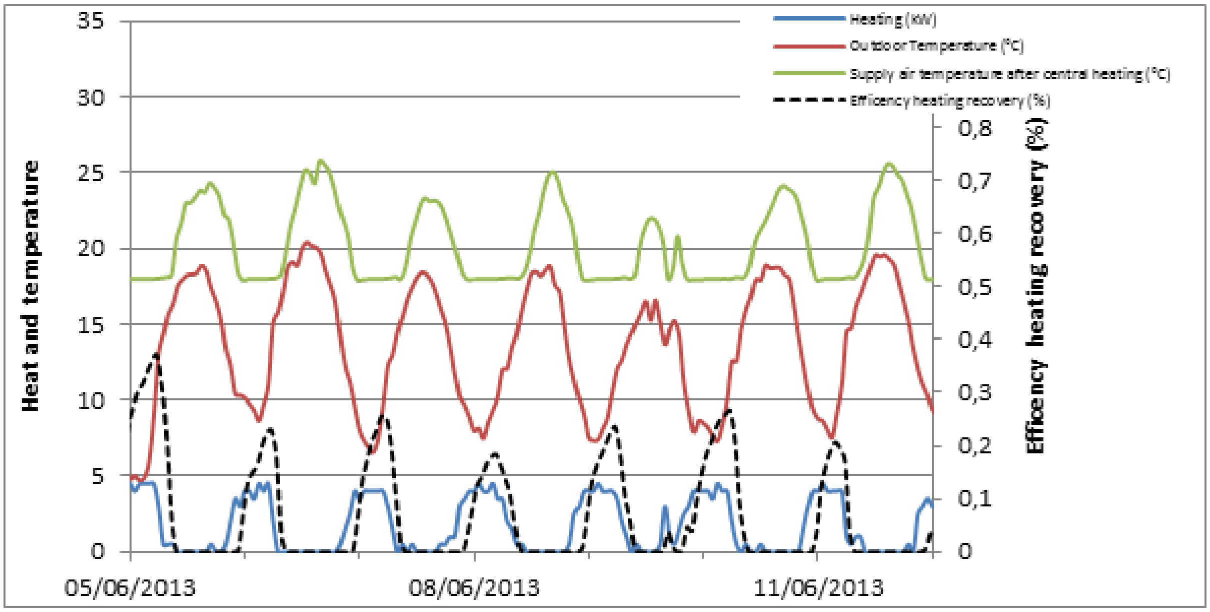


Figure 5: Changes in heating demand according to outdoor temperature and supply air temperature.

These first results have been transmitted to the construction company (Skanska) and the building owner (Alingsåshem). Together with their subcontractors responsible for the ventilation and heating they have come up with a new control strategy. A new strategy for regulation of the heating and ventilation systems has been implemented in November 2013 to avoid the unnecessary use of heat.

After the winter of 2013/2014 the heating and ventilation system was analysed again to see if the improvements that were made had given any results. Figure 6 and Figure 7 show the outdoor temperature, the efficiency of the heat recovery system, the supply air temperature and the heating power in February 2013 and 2014.
In 2013 it seems like the heat exchanger was used to regulate the supply air temperature. It can be seen that whenever the outdoor temperature increases both the heating and the efficiency of the heat exchanger decreases. The efficiency of the heat recovery is low and very unstable (the blue dotted line). After the adjustment performed in November 2013, it can be seen that the efficiency of the heat recovery system has increased dramatically and it is above 80 % during all February 2014 and the heat is on add as a complement if needed.

Another difference between the two periods is that the set point for the supply air temperature after the heat exchanger has been increased from 18 °C to 21 °C thus allowing the heat exchanger to extract more energy from the exhaust air. This in turn decreases the need for district heating in the central heater after the heat exchanger.

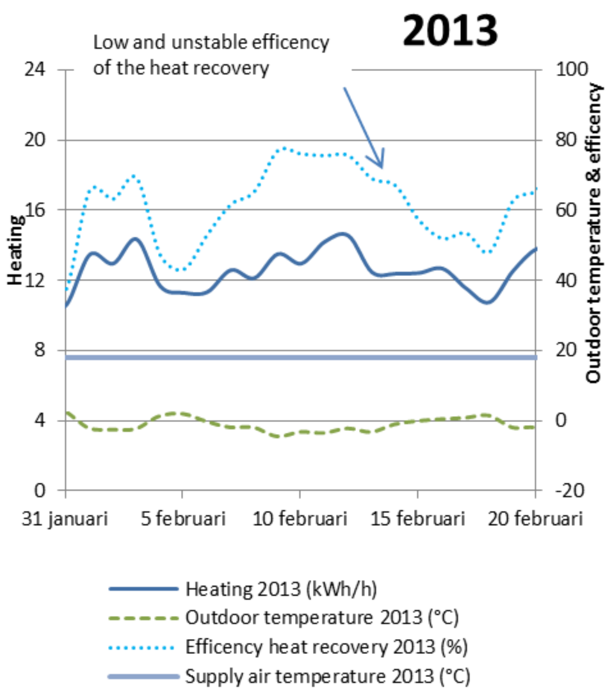


Figure 6: Heating power, supply air temperature, outdoor temperature, and efficiency of heat recovery in February 2013

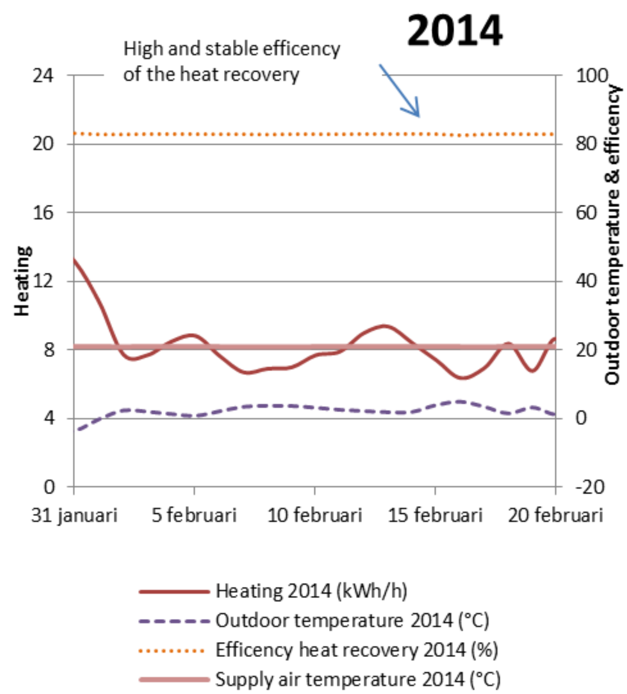


Figure 7: Heating power, supply air temperature, outdoor temperature, and efficiency of heat recovery in February 2014

In order to take into account this changing in control strategy within the analysis of monitoring results, two different reporting periods are considered.

	Period considered	Control strategy
Period 1	Dec 2012- Nov 2013	Before adjustment of control strategy
Period 2	Dec 2013 – Nov 2014	After adjustment of control strategy

Table 10: Periods considered after refurbishment for the monitoring analysis and corresponding to the two different control strategies.

The following graph shows the monthly use of district heating not HDD adjusted for the baseline period as well as for the two periods considered after refurbishment. The data displayed for the baseline period is a mean of the monitoring of 2007 and 2008.

The use of heat is reduced even further in the second reporting period after the changes in the control strategy for the heating and ventilation. It can be seen that no energy for heating has been necessary during the summer months of 2014.

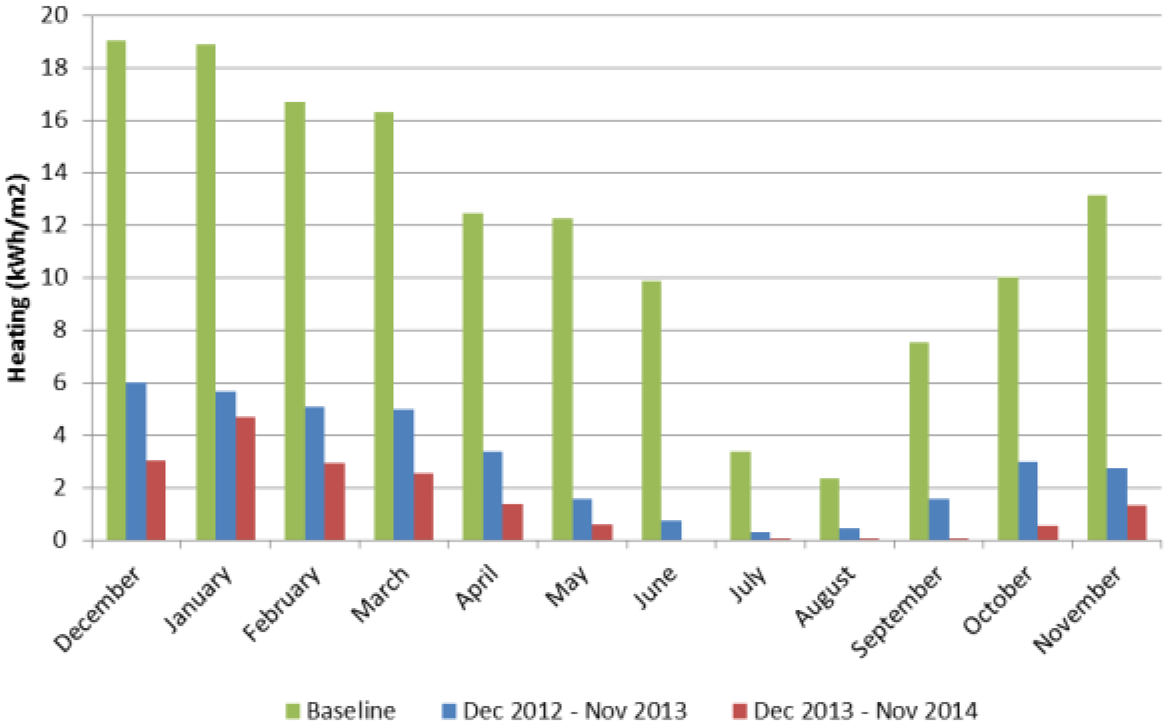


Figure 8: Monthly use of district heating for heat not HDD adjusted in Brogården.

In Table 11, the used heating for the two reporting periods are presented together with the mean outdoor temperature.

	Unadjusted values	Adjusted value	Mean outdoor temperature
	kWh/m^2,year	kWh/m^2,year	°C
2013	35.4	37.9	7.9
2014	17.1	28.7	11.5

Table 11: Summary of heating use results for the whole year.

In the figure below the heating power is presented for representative periods. The heating power has decreased during all seasons. Most of the time in January 2014, the temperature was somewhat higher which of course influences the result.

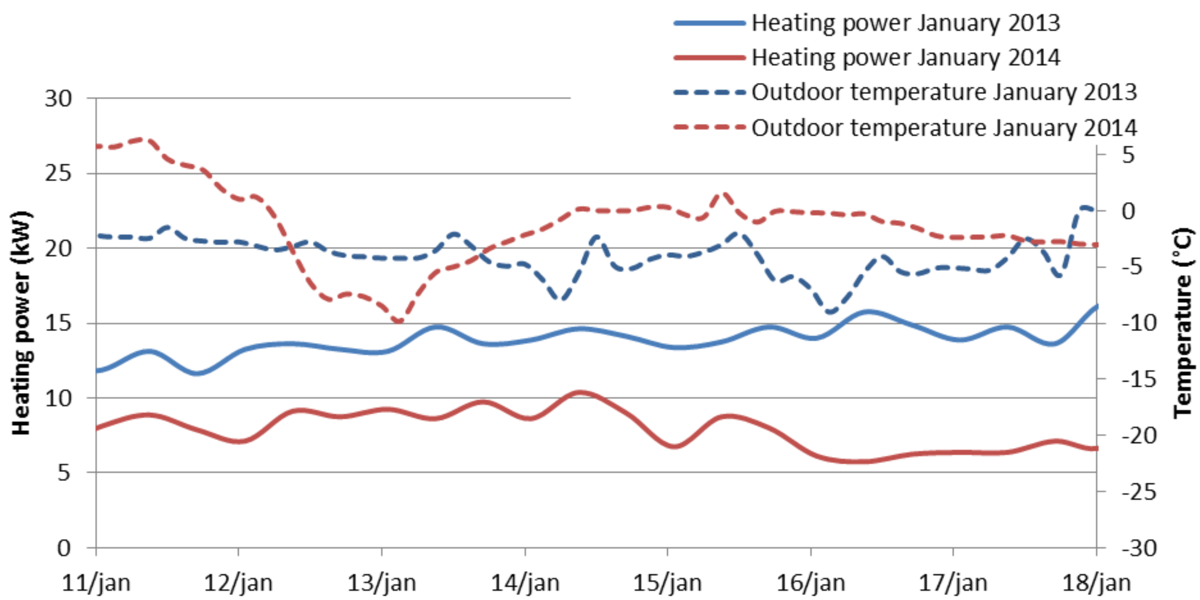


Figure 9: Changes in heating power for representative weeks in January 2013 and 2014.

During the spring the heating power is strongly dependent on the outdoor temperature. As soon as the temperature decreases, the heating power is increased (Figure 10). In a low energy building it could be anticipated that the heating would not be so directly affected by the outdoor temperature.

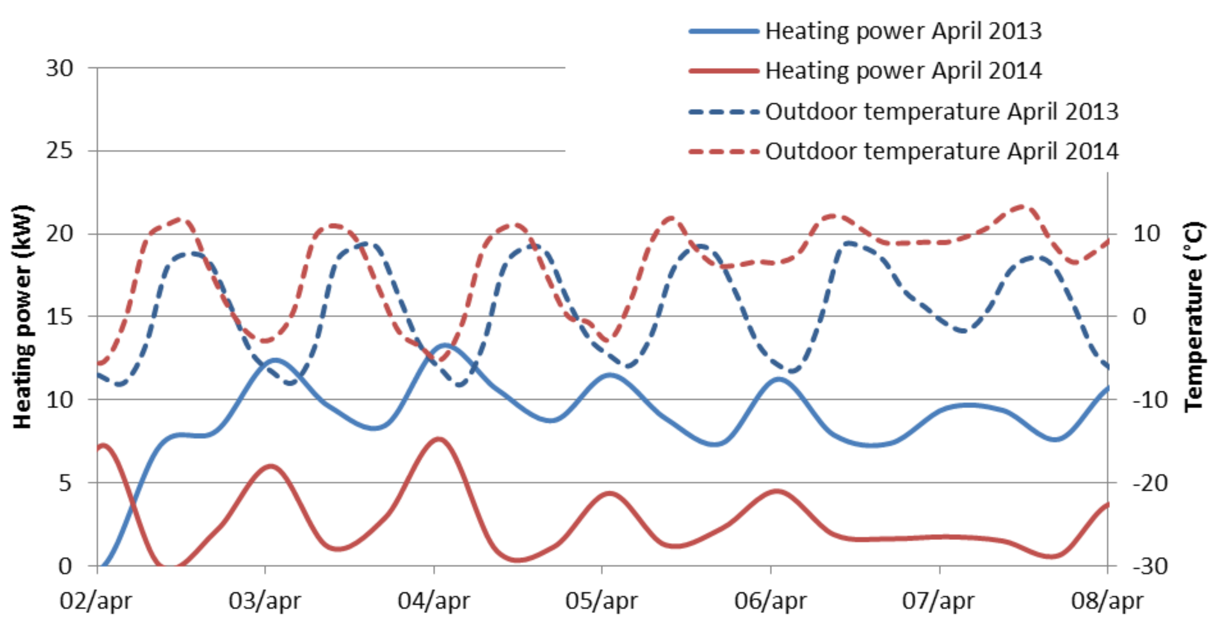


Figure 10: Changes in heating power during spring 2013 and 2014

During summer a great difference between the two reporting periods is observed (Figure 11). In June 2013 the heating is turned on each night when the temperature drops. In June 2014 on the contrary the use of heating is close to zero.

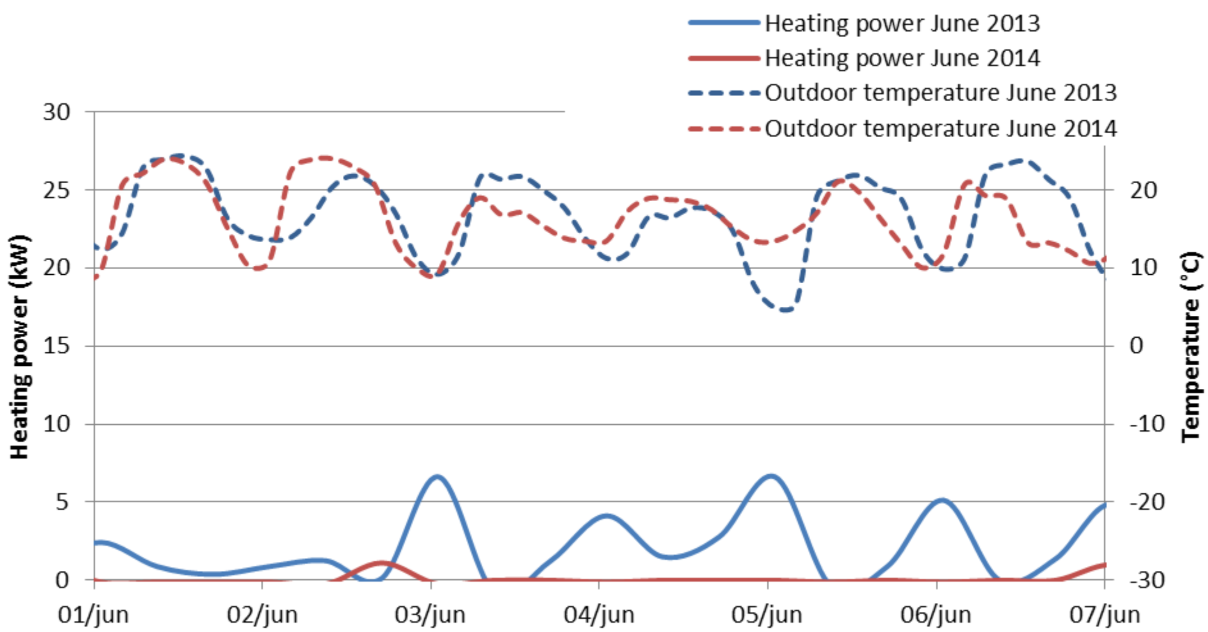


Figure 11: Changes in heating power during summer 2013 and 2014

The calculations of heating degree day adjustments are based on the balance temperature of the building. The balance temperature is a function of the outdoor temperature and the heating. The balance temperature is the temperature above which the heating demand is zero.

For a normal house the balance temperature is typically above 20 °C. A low energy house uses less energy and has a different balance temperature. In the figure below the balance temperature for 2013 and 2014 is presented. Both figures present results after the refurbishment. Figure 13 shows heating power after the adjustment of the regulation of the heating and ventilation. Note that the figure does not show numbers for an entire year.
According to the graphs, the balance point is around 20 °C, a much higher balance temperature than one could expect. This is also reflected in the fact that the house uses much more energy than predicted.
The power needed for a given outdoor temperature has decreased. For an outdoor temperature of 5 °C the heating power for the first period is approximately 8 kW but whereas for the period after changes in regulation the need is 6 kW.

It can also be observed that the balance temperature has changed. In Figure 12, the need for heating power is zero when the outdoor temperature reaches 21 °C. After changes in the regulation the balance temperature is down to 15 °C. This means that when the temperature is above 15 °C there is no need for additional heating with district heating, the house is self-sufficient concerning heat.

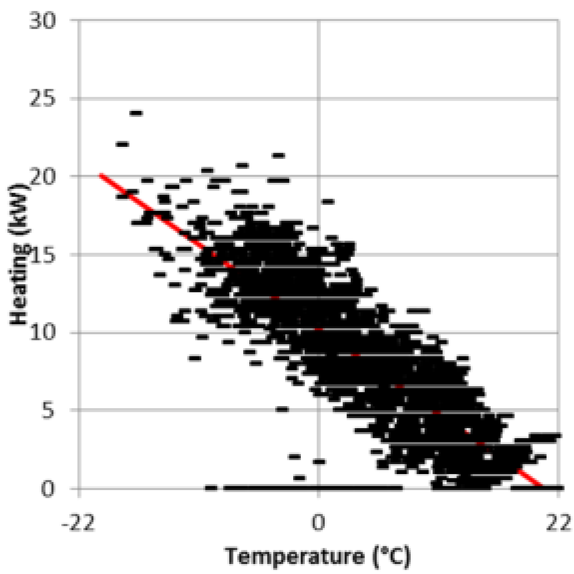


Figure 12: Heating power as a function of the outdoor temperature from December 2012 until November 2013.

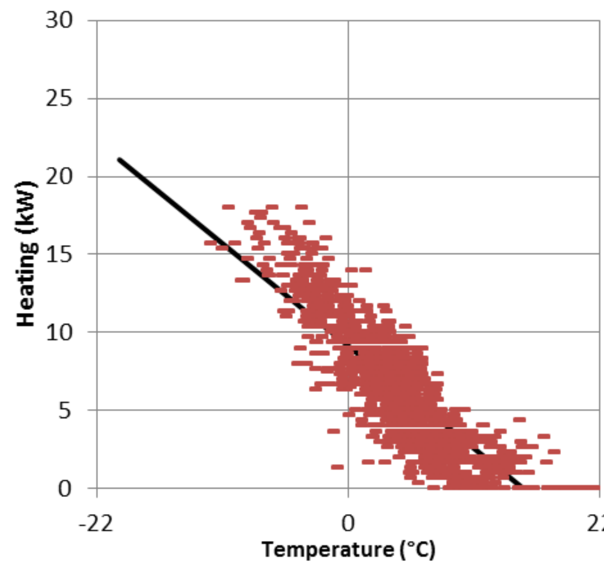


Figure 13: Heating power as a function of the outdoor temperature from December 2013 until November 2014.

When changing the regulation of the heating and ventilation in November 2013, the balance temperature changes.
Thus the balance temperature for 2014 is different from the one of the first reporting period.

	Normal year	Dec 2012- Nov 2013	Dec 2013 –Nov 2014
Mean outdoor temperature (°C)	7	7.9	11.5
Correction factor	1	1.07	1.56
Balance temperature (°C)	-	20.7	15.3

Table 12: Summary of the calculation for heating degree day adjustments.

The following table shows a comparison between the data obtained for the baseline period (2007-2008) and those that were collected for the reporting period (2013-2014). The predicted performance of the building is also provided in the table (provided by the WP1). These results show that a large decrease in heating consumption has been achieved after the building refurbishment (73% of savings for reporting period 1 and 80% for reporting period 2) but the predicted value is not reached.

	Measurements			Predictions
	Baseline period	Reporting period 1 (dec2012-nov2013)	Reporting period 2 (dec2013-nov2014)	Predicted performance after refurbishment (WP1)
	kWh/m^2, year	kWh/m^2, year	kWh/m^2, year	kWh/m^2, year
Heating*	141.8	37.9	28.4	15.1
Savings acheived (%)		73	80	--

**Heating degree day adjusted values*

Table 13: Summary of use of heating for the baseline and reporting period, included is also the predicted performance of the building (WP1 results). All figures are Atemp adjusted.

1.3.3 Electricity

For the baseline period the sum of common electricity and domestic electricity was monitored since there was only one common meter. On the other hand, for the reporting period, the domestic electricity and common electricity were monitored separately.

Therefore comparison between baseline period and reporting period is done by comparing the sum of used electricity. For analysis of the behaviour of the tenants monitoring of the domestic electricity for the reporting period is used. However it is difficult to make comparisons between baseline and reporting period concerning the use of domestic electricity due to the difference in monitoring. It should also be noticed that the tenants living in the building before the refurbishment have moved out and been replaced by new tenants after refurbishment.

The following table gives a comparison between the electricity consumption for the baseline and the reporting period. The comparison between the data collected for the reporting period and the data measured for the baseline period shows a decrease in electricity consumption (sum of domestic and common electricity) of around 35% for both reporting periods.

	Baseline period	Reporting period 1	Reporting period 2
	kWh/m^2, year	kWh/m^2, year	kWh/m^2, year
Domestic electricity	-	21.4*	22.2*
Common electricity	-	9.1*	9.1*
Sum electricity	48*	30.5**	31.3**

**Monitored value*
***Sum of domestic and common electricity*

Table 14: Use of electricity- Comparison between baseline and reporting periods

1.3.3.1 Domestic electricity

For the baseline period the domestic electricity is not measured separately as discussed in the previous section. It is measured together with the common electricity of the building.

A comparison with an estimate made by the Swedish industry standard (SVEBY[2]) is made in Table 15 (http://www.sveby.org/wp-content/uploads/2012/10/Sveby_Brukarindata_bostader_version_1.0.pdf). These figures indicate that the tenants in building H in Brogården use less energy (30% less) than what can be expected in a normal Swedish home.

	Domestic electricity
	kWh/m^2,year*
Estimate from SVEBY	30
Reporting period (BEEM-UP)	21

** Area = Atemp*

Table 15: Use of domestic electricity - Comparison between measurements and SVEBY data

In the figure below, the sum of the monthly used domestic electricity in all apartments is presented. An almost stable electricity consumption is observed along the year with a slight decrease during the summer months (June, July, August). It can also be observed that the use of energy is similar between the years.

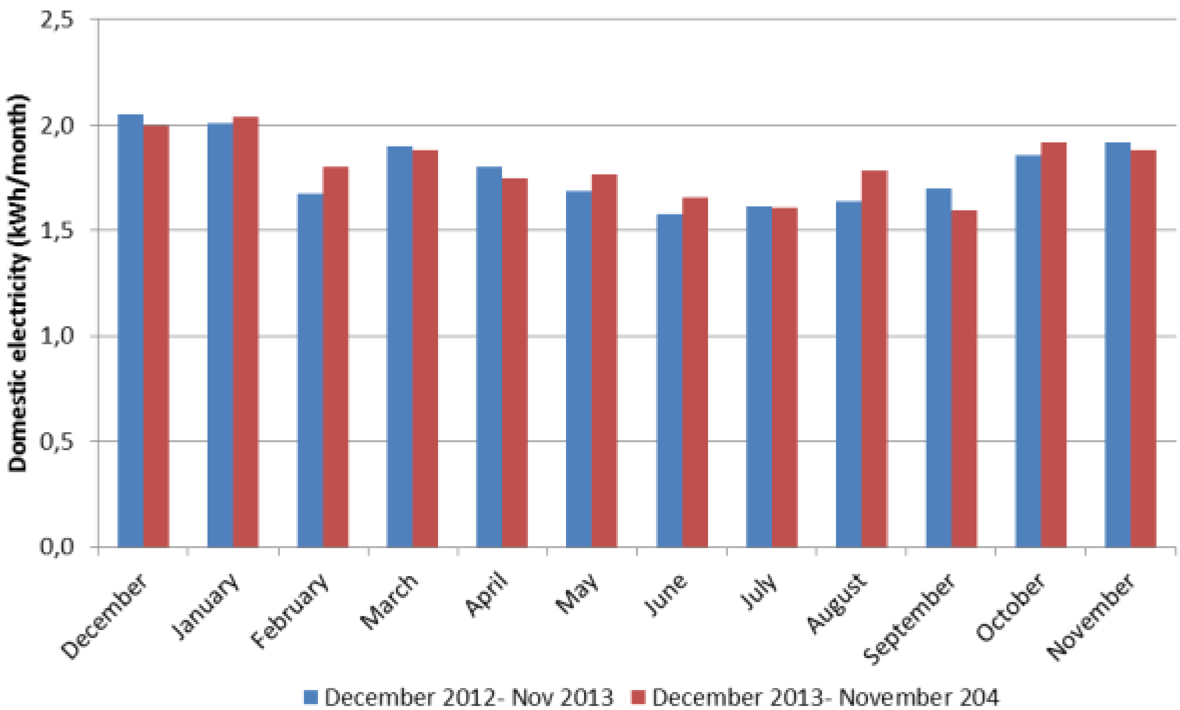


Figure 14: Sum of monthly use of domestic electricity measured during the reporting period in all apartments in building H.

[2] SVEBY stands for "Standardize and Verify Energy performance in Buildings" and is a Swedish cross-industry initiative to develop voluntary guidelines on energy use for contracts, calculations, measurements and verification.

The energy that is used is obviously dependent both on the area of the apartment as well as on the number of tenants living in the apartment.

Within this project the size of each individual apartment is clearly defined, but data on the number of inhabitants is only known in a few cases. Therefore the result for the individual apartment is presented per square meter in the Figure 15.
Apartment No. 7 has the highest use of domestic electricity per square meter. There is a single person in residence in this apartment. Even when looking at the total energy use, disregarding the size of the apartment, this tenant has one of the highest consumptions in the study. The only apartments with higher consumption are the largest flats which we assume are inhabited by families with children.

The use of domestic electricity stays rather constant between the years. In some apartments the tenants use somewhat more electricity and in others the use is a little bit lower. It is interesting to note that the tenants with the highest use of electricity during the first monitoring period are the tenants with the highest increase during the second period.

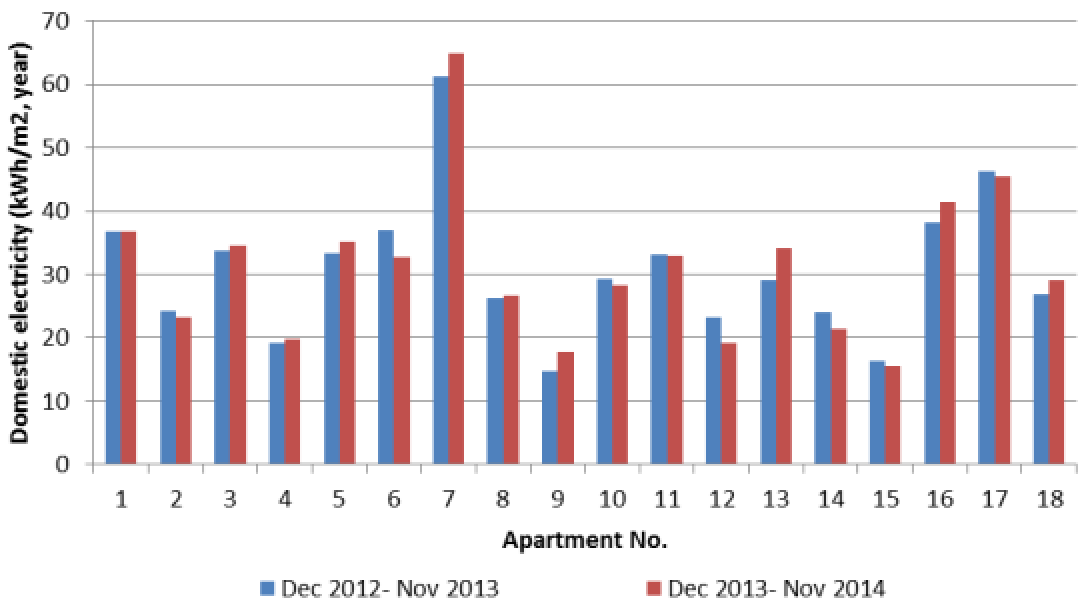


Figure 15: Use of electricity measured for each apartment in 2013 and 2014. Please note that the areas used for calculations are the areas of the apartment not A_{temp}

The use of domestic electricity changes from winter to summer. In figure below, the power measured for representative weeks for summer and winter are presented. As can be seen the power used during summer is 2/3 of the power used during winter. There is a basis load of domestic electricity of around 0.08 kW/m^2. This basis load corresponds to fridge, freezer and other electrical appliances consumptions. This load does not change in between seasons. As it could have been expected the result show that most electricity is used during the evenings.
During summer seasons the peak load is 2/3 of the peak load during winter. The decreased need for light is one of the explanations for the lower usage of electricity; another could be the fact that people spend less time in front of television and computer during summer.

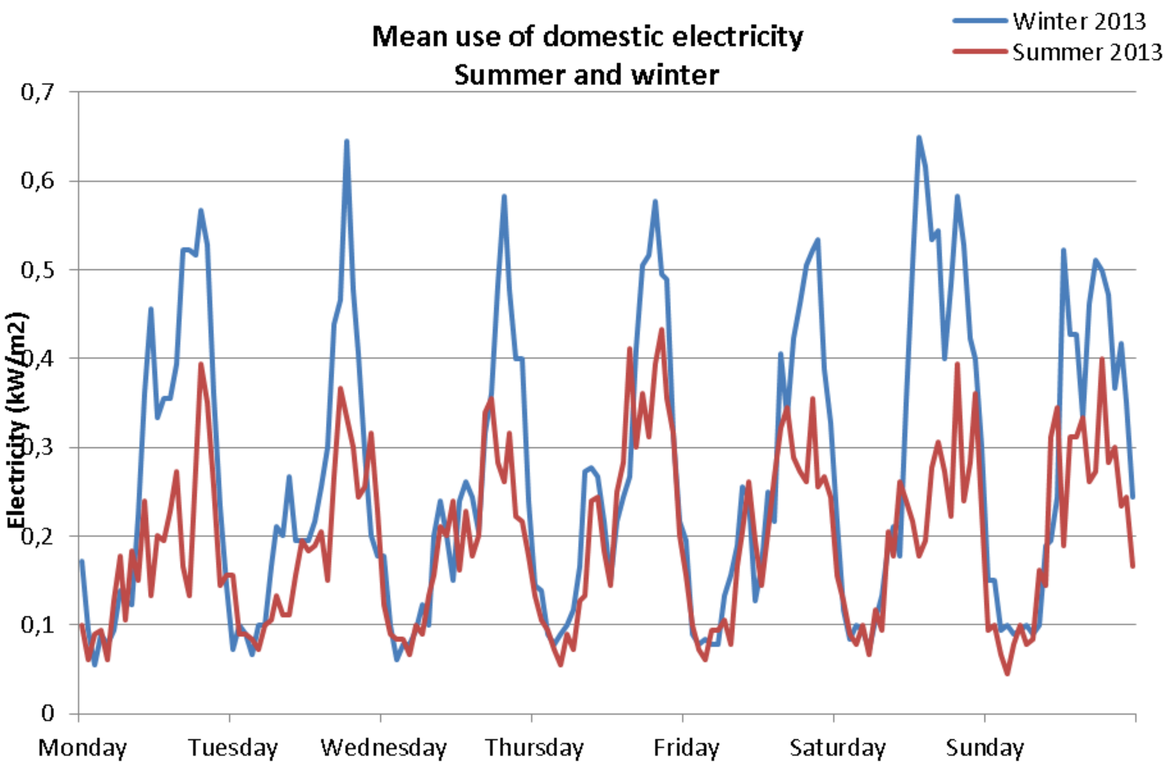


Figure 16. Average use of domestic electricity per square meter during a representative week in January and June 2013

Comparison between baseline period and reporting period is not possible since the domestic electricity for the baseline period has not been measured separately; common electricity and domestic electricity have been measured together.

1.3.3.2 Common electricity

The common electricity for the reporting period has been measured separately. For the baseline period it can only be approximated as the difference between the total electricity and the estimated domestic electricity.

The common electricity holds not only energy for the building but also illumination for the court yard.

As shown on Figure 17, the common electricity use is very stable along the year and rather constant between the years.

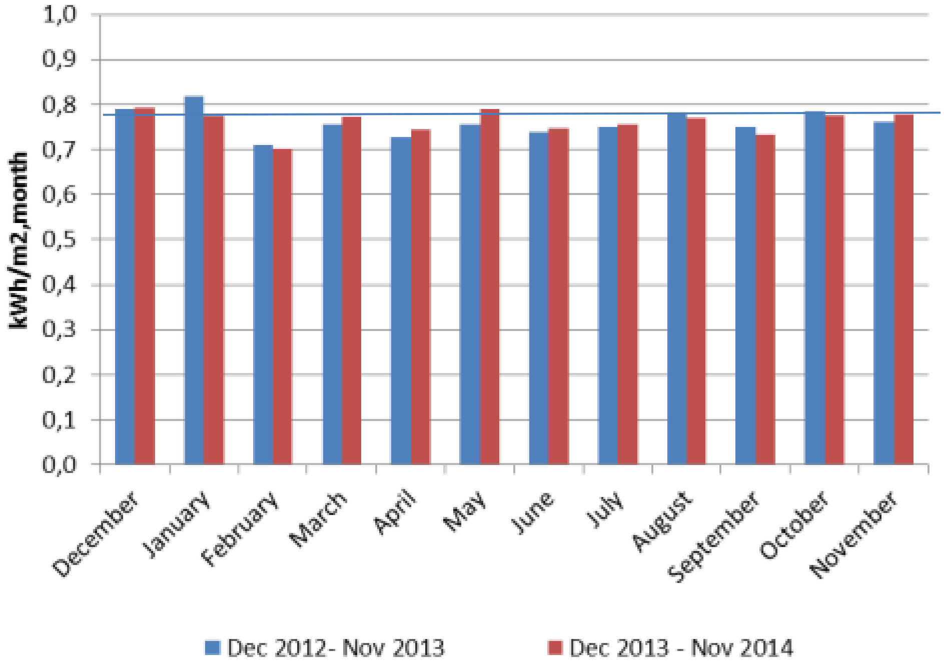


Figure 17: Use of common electricity after refurbishment

1.3.4 Domestic hot water

1.3.4.1 Analysis of DHW consumption

The domestic hot water for the baseline period is measured as a sum for the entire building. For the reporting period the hot water is measured individually for each apartment and the sum of all these individual data is performed to get the value for the whole building.

The energy used for DHW was calculated from the used amount of DHW, together with the specific energy capacity and the temperature rise of the water, see equation below.

$$Q\ (kJ) = \dot{m}\ (kg) \cdot Cp\left(\frac{kJ}{kg \cdot K}\right) \cdot dT(K)$$

Incoming water during the reporting period has an average temperature of 5 °C and is heated to 55 °C. It is reasonable to assume that the water for the baseline period held the same temperatures.

The following graph shows the monthly values of domestic hot water consumption for the baseline period and the reporting period (two reporting periods) for the whole building. The profile of DHW consumption during the year is almost the same for the baseline and reporting periods but a decrease in consumption is clearly observed for the reporting periods except for July, August and November.

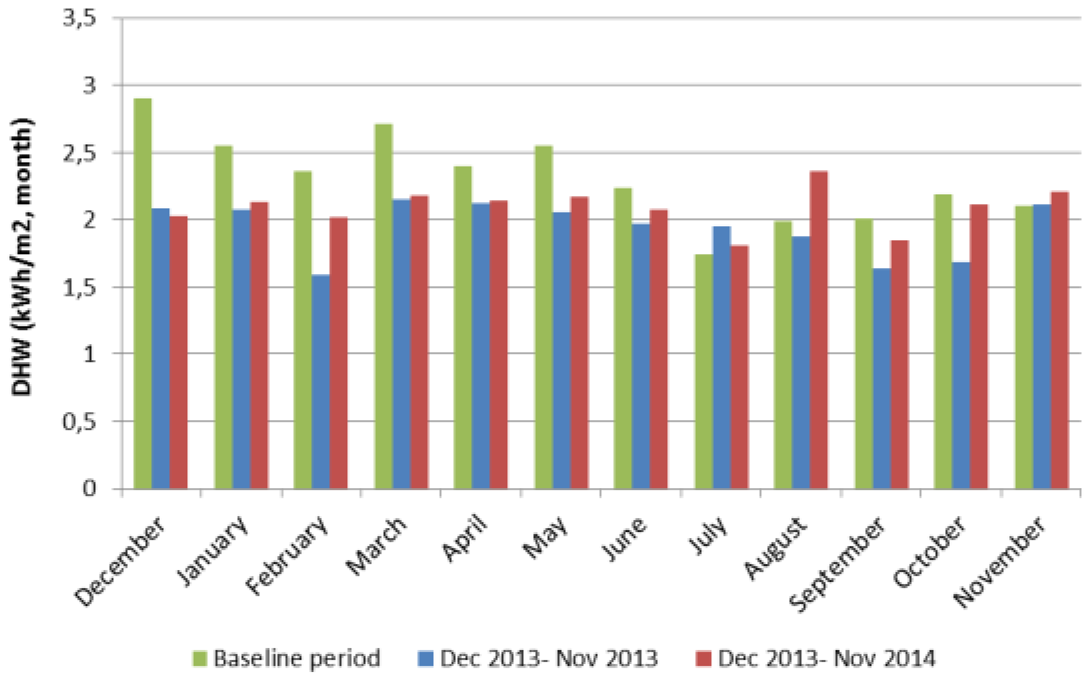


Figure 18: Monthly use of domestic hot water for the whole building – Comparison between baseline and reporting periods

Figure 19 shows the changes in hot water consumptions for representative weeks of winter and summer periods. Compared to the measurements of the domestic electricity, the usage of domestic hot water is more fluctuating. During the nights the usage decreases to zero thus indicating there is no leakage of hot water from e.g. taps.

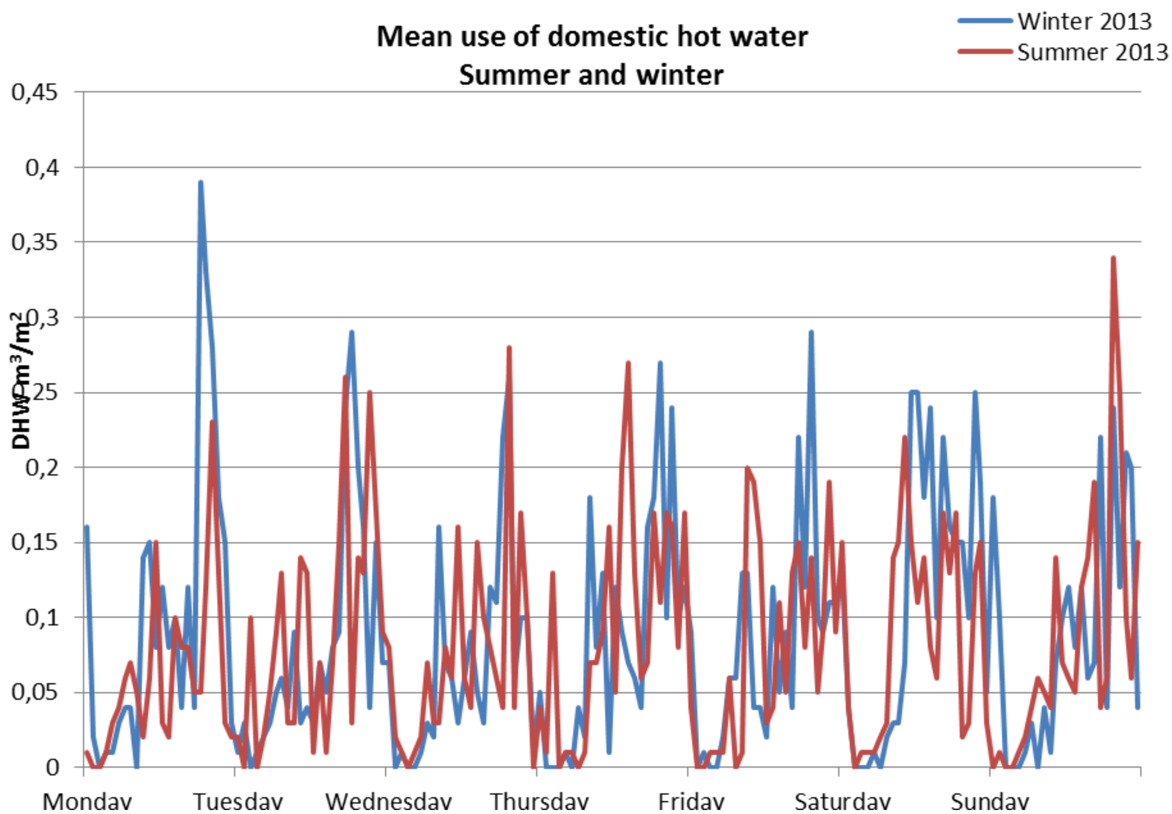


Figure 19: Use of domestic hot water for the whole building during representative weeks of the winter and summer periods

The use of domestic hot water is lower for the reporting period than for the baseline period. Before the refurbishment the installation consisted of ordinary water taps. During refurbishment the taps where replaced by more low-flow taps. This is one of the reasons for the decrease. When comparing the baseline and reporting period it has to be reminded that all tenants are new after the refurbishment. The behaviour of the tenants has therefore a real influence on the hot water consumptions changes.
The table below shows the comparison between the data collected for the baseline period and the data collected for the reporting periods. This comparison shows a decrease in DHW consumption between 8 and 16% (average 12%). The predicted performance (WP1 simulations) provides a reduction of DHW consumption of 12.5%. Therefore the figures related to DHW savings are well aligned with the predictions and the absolute values of DHW consumptions are relatively close to the prediction as well. In the overall goal of the BEEM-UP project the reduction of DHW should be 45%. This goal can be seen as overambitious and not realistic to achieve.

House H	Baseline period	Reporting period 1	Reporting period 2	Predicted performance before refurbishment	Predicted performance after refurbishment
	kWh/m^2,year	kWh/m^2, year	kWh/m^2, year	kWh/m^2, year	kWh/m^2, year
Domestic hot water	27.7	23.3	25.5	23.3	20.4

Table 16: Use of domestic hot water - Comparison between baseline and reporting periods. The predicted performance are the calculations made in WP1

The following graph shows the DHW consumption at dwelling level measured after refurbishment. Here again heterogeneous behaviours are observed, but no correlation is observed between the DHW consumption and the use of electricity. It can be seen that most of the tenants have a consistent use of DHW between the two periods. The major changes in behaviour for apartment no 1 and 3 can be both correlated to a change in number of tenants.

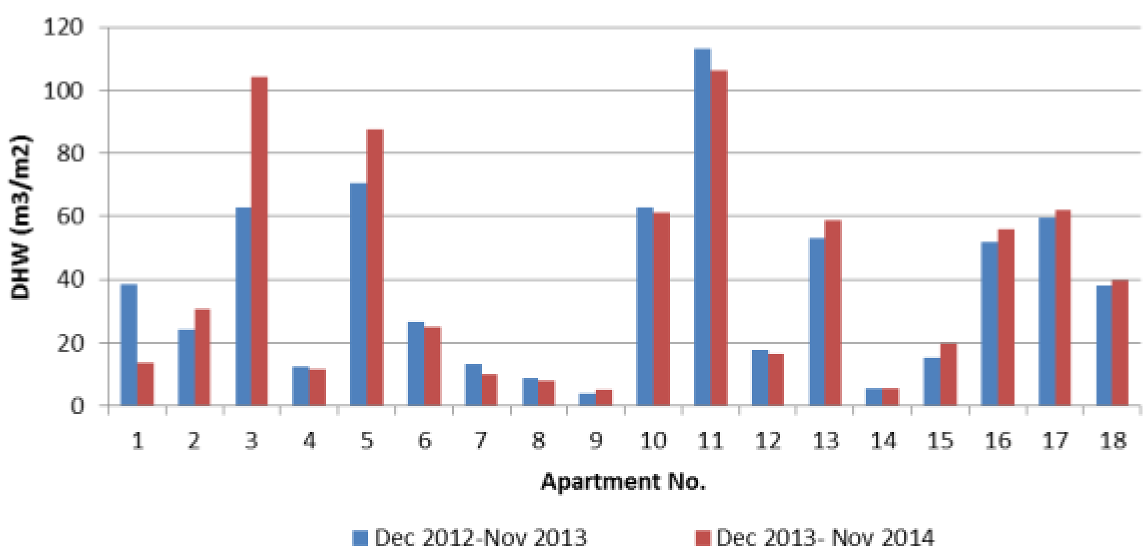


Figure 20: Sum of DHW consumptions per year measured at dwelling level for the two periods after refurbishment. For the baseline period no monitoring was done at dwelling level

1.3.4.2 Analysis of circulation losses

The domestic hot water is built with a circulation circuit so that there is always hot water available for the tenants. The construction was the same for both the baseline and the reporting period. When circulating in the tubes of the building the water loses energy to the surroundings. In the case of Brogården the circulation circuit serves several buildings so the energy losses cannot be said to gain the heating of the house but should be considered as mere losses.

For the baseline period there was no measurement of the circulation losses. For the reporting period a flow meter has been installed to measure the returning water that is only circulated. The energy loss was calculated in the same way as the energy for domestic hot water (see equation above). The temperature loss was measured and as a mean over the year the circulating water losses 4 °C. The energy loss due to the water circulation is around 11 kWh/m²·year.

Parameters characterizing the circulation losses		
Flow rate (average)	2,8	m^3/h
Return temperature (average)	51	°C
Supply temperature (average)	55	°C
Circulation losses	11	kWh/m^2*, year

*Atemp

Table 17: Result of measurement of the hot water circulation losses.

The monitoring of the circulation losses is seldom done and the results from Brogården show a lower value than normal estimates. E.g. SVEBY gives an estimate of 25 kWh/m^2.year. So the results of these measurements give a good knowledge for other projects. The circulation losses are energy that is often forgotten since they do not have to be presented. But this information could be useful to explain some results on hot water consumption.

1.3.1 Ventilation

Before refurbishment supply air was provided through natural ventilation. After refurbishment the ventilation is fully mechanical, with fans in both the supply and exhaust air.
Since the difference in the ventilations system are so big it is not feasible to compare the baseline period to the reporting period when it comes to the ventilation system itself. However the ventilation affects the indoor climate, which is covered in section 1.3.2.
This section aims at analysing the ventilation system after refurbishment in order to identify if it fulfils the existing requirements in Sweden.

Specific Fan Power (SFP) is a parameter that quantifies the energy-efficiency of fan air movement systems. It is a measurement of the electric power that is needed to drive a fan (or collection of fans), relative to the amount of air that is circulated through the fan(s). It is not constant for a given fan, but changes with both air flow rate and fan pressure rise.

SFP is a common way to evaluate a fan and is regulated in Swedish requirement and therefore a good indicator of how efficient the fan is. A low SFP-value indicates an energy effective fan.

$$SFP = \frac{\sum P}{q_v} \frac{[kW]}{[m^3/s]}$$

	Measured value	Unit	Remarks
SFP (average)	1,7	$kW/m^3.s$	Fulfills Swedish requirements of SFP < 2,0 $kW/m^3.s$ for air handling units with mechanical supply and exhaust air with heat recovery.
Supply air flow rate (average for the building)	0,46	$m^3/(s.m^2)$*	Fulfills Swedish requirements of > 0,35 $m^3/s.m^2$
Fan power (average)	1260	W	

*Atemp

Table 18: Ventilation parameters measured and comparison with Swedish regulation

The supply air flow rate has to be at least 0.35 $m^3/s.m^2$ (Atemp) according to Swedish requirements. In the table above the mean supply air flow rate for building H is presented. The mean value is 0.46 $m^3/s.m^2$ for the reporting period, well above the requirements.

1.3.2 Indoor temperature in the dwellings

A good indoor climate depends on a number of factors. Within the BEEM-UP project three of these factors have been measured: temperature, relative humidity and CO_2 concentration.
In addition to the results analysis regarding the project objectives, the results from the measurements should be compared to Swedish regulation and advices.
In Sweden, the Swedish National Institute of Public Health gives advices about the indoor temperature.
In a handbook written by The National Board of Health and Welfare it is said that a good thermal comfort is achieved with a temperature between 20 and 24°C. The Swedish climate has mostly generated problems with too cold indoor temperatures. However in well insulated low energy houses (which is the case for the pilot site), problems with too high temperatures have been raised. The problem occurs during spring and autumn when the sun stands low and the radiation can reach directly into the apartments. During summer the sun is stopped by solar protection but these can be insufficient when the sun stands low in spring and autumn. In Brogården house H the balconies serve as solar protection to the south. However the stairwells lack of solar protection.

The thermal comfort is also affected by other factors and the feeling that the apartment is cold does not necessary means that the temperature is low but could be caused by draught, cold radiation, floor temperature and temperature differences within the room.
Before renovation earlier projects have shown significant problems with draught in the apartments. Even though no measurements were made it can also be assumed that cold radiation from the windows and cold floor had a negative impact on the thermal comfort.
After renovation the windows are changed to well-insulated windows, the better isolation gives less cold radiation. The thorough work conducted to minimize all leakage in the building means that it can be assumed that there is a minimum of draught in the apartments.

The Swedish law demands that the housing occupants should have a minimum knowledge of the indoor climate of their housing. Moreover Alingsåshem guaranties the tenants a minimum indoor temperature of 21°C. The calculations done in work package 1 to predict the energy performance of the building is also done for a temperature of 21°C.

The indoor climate measured in dwelling No 1 and No 4 is shown on the following graph. The indoor climate is similar in all monitored apartments. These measurements show that the indoor temperature is well above the temperature guaranteed by Alingsåshem (21°C) during the whole year and even during the winter periods.
During summer months and especially in the summer of 2014 the temperature get high, especially in apartment no 1. This is a small apartment with windows facing to the south, thus making it extra sensitive to solar irradiation.

The changes in the heating and ventilation system (November 2013) has not affected the indoor temperatures in the building negatively. Both during winter 2012/2013 and 2013/2014 the temperatures remain well above 21 °C.

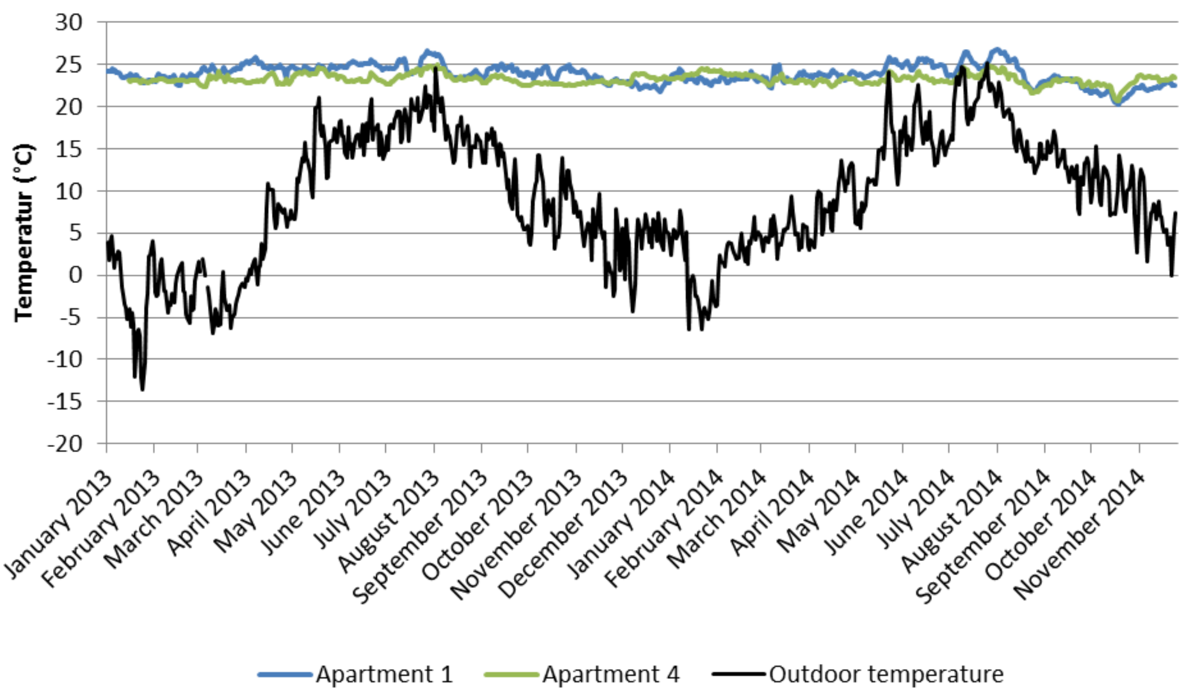


Figure 21: Indoor temperature measured during the whole years 2013 and 2014-Daily average for dwelling#1 and #4

The results obtained from the humidity measurements are shown on the following figure. The relative humidity level remains below 60% whatever the season. The indoor humidity is closely linked to the outdoor temperature. These measured parameters highlight the improvements led by the improvement measures selected (mechanical ventilation system with a rotating heat exchanger).

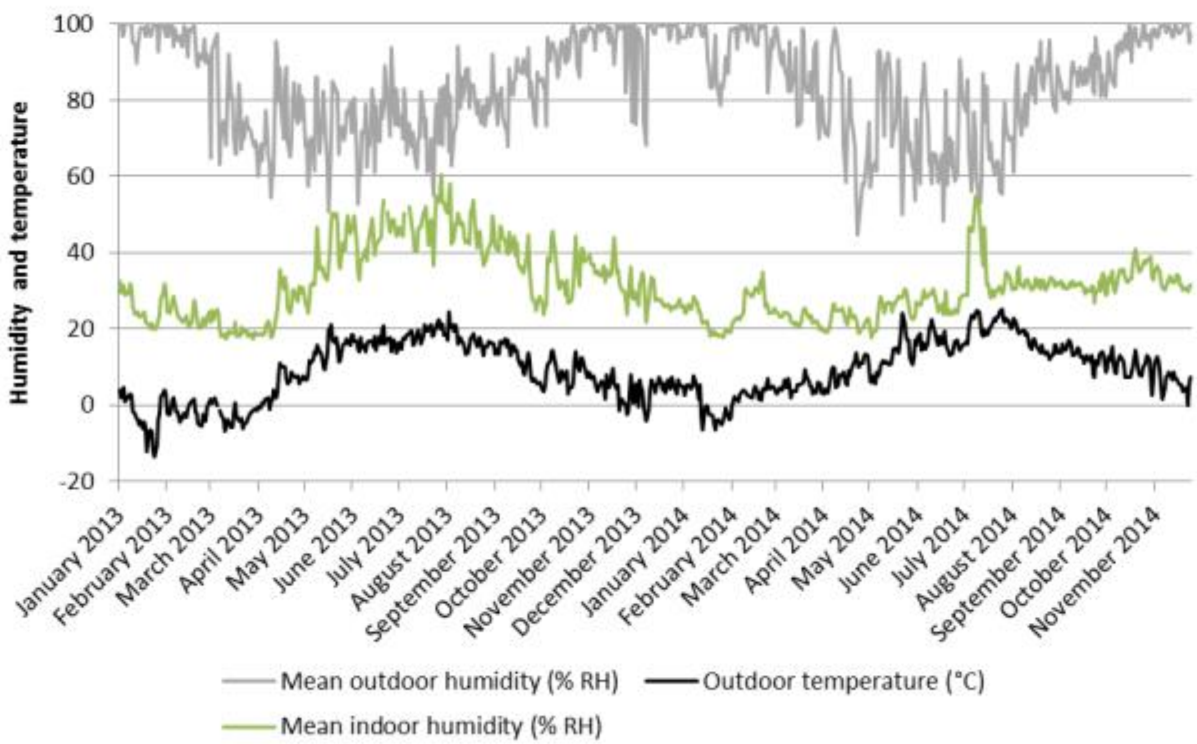


Figure 22: Mean indoor humidity compared to outdoor humidity and outdoor temperature. Daily mean of the monitoring in several apartments.

The indoor climate has been monitored in dwellings as well as in common areas such as the basement and stairwell. The results are shown on the following graph. The temperatures reached in the stairwell and the basements are a little bit lower that the ones measured in the dwellings but always above 20°C. Concerning the humidity, the same trend is observed for the humidity measured in the basement as the one identified in the dwelling.

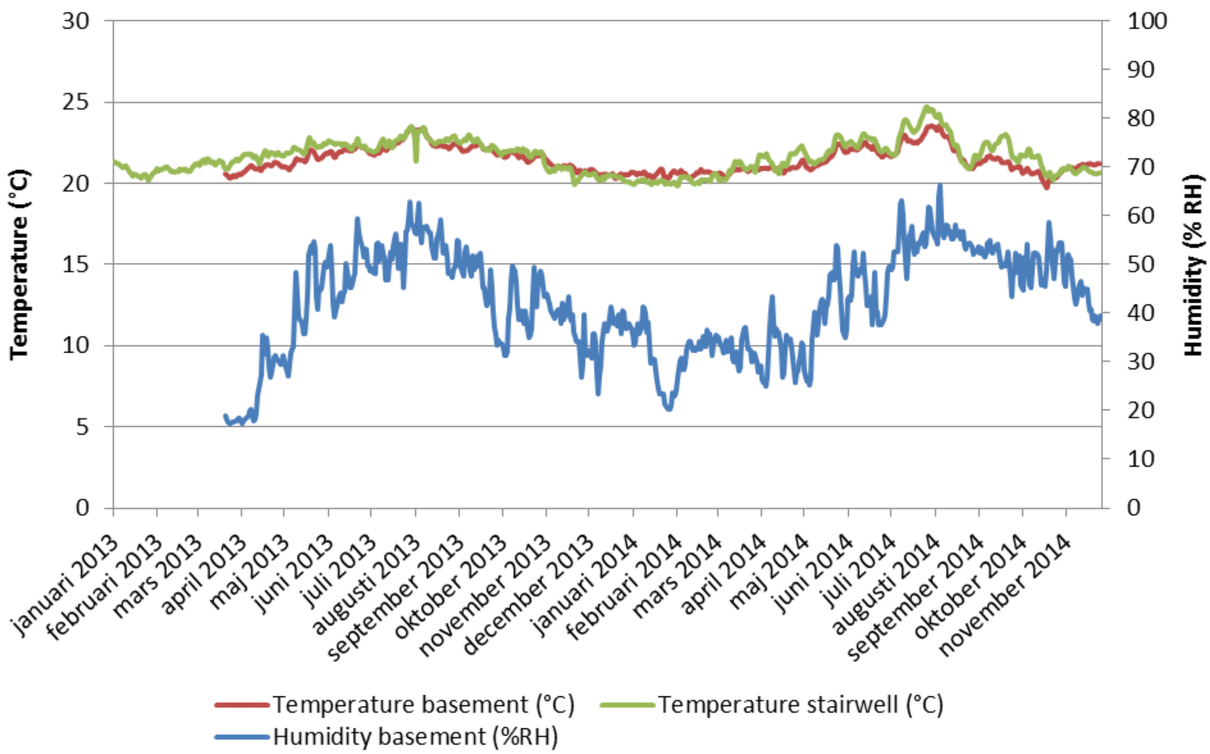


Figure 23: Temperature and humidity measured in common areas such as basement and stair well

The concentration of carbon dioxide is an indication of air quality. Even though not dangerous, a concentration above 1000 ppm indicates a poor air quality and reveals a ventilation system that is not well functioning or which is not optimized. The carbon dioxide was monitored as an indication if there were any disturbances in the new ventilation system after refurbishment. The amount of carbon dioxide itself is not harmful but a high level indicates that the level of other substances could be increased.

The following graph shows the CO_2 concentration in one apartment during 2013 and 2014. This specific meter was placed in the living room at a height of 1.1 m. The results show that the level of CO_2 is well below 1000 ppm. This result is in line with the measurement of the air flow that fulfils the Swedish requirements of more than 0.35 $m^3/s.m^2$ (see section 1.3.1).
The levels of CO_2 are suddenly decreasing in late summer 2013 indicating that the tenants are not at home during this period. This assumption is confirmed when analysing the use of the domestic electricity during the same period as the use is close to zero.

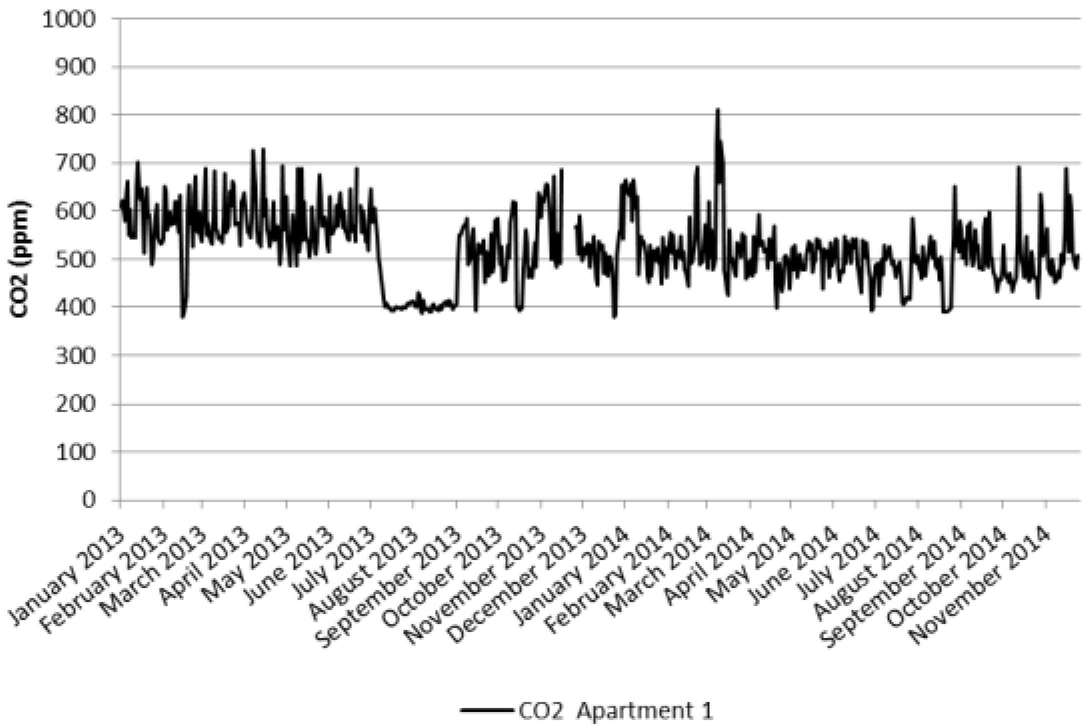


Figure 24: Results of monitoring of CO_2 in one apartment during 2013 and 2014. Daily mean values for one apartment.

1.4 Conclusions for Alingsås site

1.4.1 Energy savings reached and comparison with predicted performances

The following table summarizes the main results obtained in terms of energy savings and provide a comparison with the predictions and the general objectives of the project.
In WP1, calculations were done to determine the theoretical energy performance of the building before and after refurbishment. First the buildings were analysed, all stakeholders gave input about goals, legal requirements, technical possibilities, cost, and energy saving potential. Then the targets were defined (ecological, economic, social aspects), single measures were developed as well as combinations. And finally, this led to a methodology to choose very good performing variant in all three dimensions of sustainability. The calculations for Alingsås were conducted using an operative temperature of the buildings of 21°C.

As indicated in Table 19, the use of domestic hot water, electricity and heating has decreased after refurbishment.

Nevertheless, all the energy consumptions measured (heating and DHW) are higher than the predicted one. Despite this, the savings achieved for the heating demand (80%) comply with the objectives of the project.
The savings achieved for the DHW is in line with the predictions but it is largely lower than the objectives of the BEEM-UP project. The 45% savings in energy for domestic hot water seemed to be too ambitious especially, as the consumptions are very much dependent on tenants´ behavior.

Some of the discrepancies observed between the predictions and the measurements could be explained by the fact that the calculations are made with the assumption that the heating and ventilation systems are functioning perfectly. The heating example shows that some important differences can be observed when the system has not been adjusted nor optimized.
Another explanation for the difference is that the temperature set point used for the predictions calculation was 21°C for Brogården. The monitored indoor temperatures have been well above this at all times. An average for the year has been 22-23 °C. Therefore this should be the most important difference, every degree in indoor temperature having a massive influence on consumption[3].

The electricity consumption (sum of domestic and common consumptions) that includes lighting consumption shows a decrease of 33.7%. The discrepancy between this result and the objective of the project on lighting (42%) could be explained by tenants' habits.

[3] 1°C more in the temperature set-point in residential sector corresponds to an additional energy consumption of 5 to 8% [5], [6].

Swedish site	METERED Baseline period measurements	METERED Reporting period measurements		METERED Savings achieved (%) Period1/Period2	SIMULATED Predicted performance before refurbishment (WP1)	SIMULATED Predicted performance after refurbishment (WP1)	SIMULATED Savings according to predicted performances	TARGET Objectives of the project in terms of energy savings (see DOW)
	kWh/m².year	Period 1 [dec2012–nov2013] kWh/m².year	Period 2 [dec2013–nov2014] kWh/m².year	%	kWh/m².year	kWh/m².year		%
Heating (heating degree day adjusted values)	141.8	37.9	28.7	73/80	134.6	15.1	89	**75**
Domestic hot water	27.7	23.3	25.5	16/8	23.3	20.4	12.5	**45**
Domestic electricity	Not measured separately	21.4	22.2	--	No prediction	No prediction	37 (calculated from a previous project)	
Common electricity	Not measured separately	9.1	9.1	--	No prediction	No prediction		
Sum electricity	48*	30.5**	31.3**	36/35	No prediction	No prediction		**42** (for lighting only)
Indoor climate	--		22-23°C			21°C		

** Measured value*

*** Sum of domestic and common electricity*

Table 19: Summary of results and comparison with predictions and general objectives of the project for the Swedish site

1.4.2 Comparison of monitoring results with predicted performances of the building company

A complementary comparison has been realised with data of the Swedish building regulations as well as with the building company objectives. The predicted performance of the building company has been done before the calculations in WP1 within the BEEM-UP project and is totally independent of these.
The use of domestic hot water has decreased with 8-16% from 28 kWh/m^2/year to 23-25 kWh/m^2/year. The use of domestic hot water is even lower than the predicted performance of the building company.
The use of common electricity has decreased with 35% which is exactly the same as predicted performance. It is however difficult to compare the common electricity before and after renovation since the common electricity was measured together with the domestic electricity for the baseline period.

In Sweden the building regulations regarding energy performance focuses on the term specific use of energy. This includes the heating, domestic hot water and the common electricity. The specific energy is always reported as used energy per square meter temperated area (kWh/m^2/year).
The measured data have been compared to the figures available for a newly built house located in the region where Brogården is situated[4]. The specific use of energy for this kind of house is 90 kWh/m^2.year. The table below shows this comparison. The results of the measurements show that even if the used energy does not match the predicted performance this renovated house uses 27% less energy than what is required for a newly built house in Sweden in terms of energy consumptions.

House H	Reporting period	Predicted performance according to Skanska	Building regulations
	kWh/m².year	kWh/m².year	kWh/m².year
Specific use of energy	63	47	90

Table 20: Specific use of energy -Comparison between measurements and Swedish building regulation. Specific energy includes heating, DHW and common electricity

1.4.3 Improvement in comfort conditions

The comfort conditions completely fulfil the objectives of the building owner as well as comply with the Swedish regulation. Before refurbishment the apartments where draught and there were complaints about the bad indoor climate. After refurbishment the indoor temperatures are well above 21 °C which is a minimum requirement from the building owners.

1.4.4 General conclusions

The real consumptions measured through the monitoring process are higher than the predicted one. But the discrepancy between these two sources of data can easily be explained by non-optimized functioning of the systems or indoor temperature above the temperature set-up used for the calculations.
The savings achieved are in agreement with project objectives for the heating but the 45% savings in energy for domestic hot water seemed to be too ambitious even if a 12% savings is achieved.

[4] National Board of Housing, Building and Planning. (2014). Boverkets författningsamling BBR 21. Boverket.

Chapter 2 Final reporting of monitoring results for the site of Delft

2.1 Main characteristics of the pilot site and reminder on the methodology used

2.1.1 Main characteristics of the pilot site and reminder on the refurbishment

The BEEM-UP demonstration in Delft, The Netherlands, is a refurbishment of 108 dwellings distributed over 3 types in 8 blocks. These dwellings have had similar improvements in their envelope. Some 50 dwellings have received a new installation with a solar boiler. Some 34 dwellings received a feedback system which gives occupants a real time insight into their electricity and gas consumption, as well as weekly and monthly statistics (see below and Deliverable D3.3 [4] for more information about the feedback system installed in DELFT and named TOON). It also enables the user to control the heating in the house through an application on their smart phone.

Key indicators of the pilot site	Value for the Dutch pilot site
Location	Delft (the Netherlands)
Year of construction	1958
Surface retrofitted	9128 m²
Number of dwellings	108 (28 row houses and 80 flats)
Owner/.partner	Woonbron
Level of intervention	Exterior measures and installations (tenants not evacuated during retrofitting)
Total investment	€ 3.544.000 excl. VAT

Figure 25: Key indicators related to the Dutch pilot site

The Figure 26 shows the Delft project and the different types of dwellings.

Figure 26: The Delft project has 3 types of houses in 8 blocks.

The improvement measures conducted in the site of Delft are summarized in Table 21:

Envelope	Walls: 1,7 m^2 K/W Basement/floor: 1,7 m^2 K/W Roof: 4,0 m^2 K/W Floor uninsulated
Windows	HR++ argon filled windows with a reflective layer. 1.6 times better insulation than double-glazing. ($U_{window} \leq 1.2$ W/m²/K)
Heating (source and distribution)	Fossil gas. Option of new condensing boilers and solar collectors per flat (about 50%). HR 107 boiler with use of solar panels on the houses. Insulated distribution. Waterborne system with radiators offered, individually controlled per radiator.
Domestic hot water	Decentralized systems, heated by fossil gas. Water saving showers.
Ventilation system	Natural ventilation. New windows equipped with ventilation openings
ICT – energy management (incl. smart meters)	Feedback system (TOON, see description below) mounted to the wall and including both functions to set temperature and weekly schedule as well as feedback on actual usage of electricity and gas.

Renewable Energy Source	Solar energy on roof for warm water and heating.
Other energy saving	Focus on tenant behaviour and awareness-raising during and after retrofit is expected to lead to further reductions in energy consumption

Table 21: Improvement measures conducted in the site of Delft

The TOON feedback system is connected with an ENECO (the energy supplier) based server through internet via the home Wifi router. Energy consumption data from the regular meter is transferred wirelessly (Z-wave) to TOON within the homes. TOON allows users to compare at a glance gas and electricity with consumption in recent days, weeks and months. It is possible to instantly see how much energy appliances consume. This helps users to be more aware of energy consumption. TOON notifies users when actual consumption is higher than the estimated consumption by ENECO. TOON offers detailed information about actual energy costs through continuous updates of current rates.

Figure 27: "Toon" analog reading of individual meters and TOON interface

Renovation activities in Delft

The general timeline of the refurbishment process is shown in Figure 28. The figure also shows the installation of smart-meters and feedback systems in the site.

The windows and glazing have been replaced in the period November 2011 to December 2012, the insulation of the roof in the first months of 2012, while extra's, such as the home energy management system, modern central heater and solar domestic hot water systems have been installed in 2012 and up to May 2013.
The energy meter readings are normally done at the end of May to beginning of June. This implies that the energy data of June 2011-May 2013 have both before and after renovation characteristics, which may distort the comparison. The data of 2013-2014 are available for all 108 dwellings, while the monitoring of 30 dwellings with the home energy management system was planned. Comparison with the reference situation of the period June 2009-May 2011 and June 2013-May2014 is the most reliable. However, the winter of 2013-2014 was a peculiar winter with a short cold period and warm spring. The degree-day correction factor is quite high and may not be reliable, because people tend to heat less in

very cold periods and more in relatively warm winter periods than the degree-day correction suggests. Also, the energy data have to be corrected for non-heating purposes first, because the correction based on degree days is relevant for the heating energy use only.

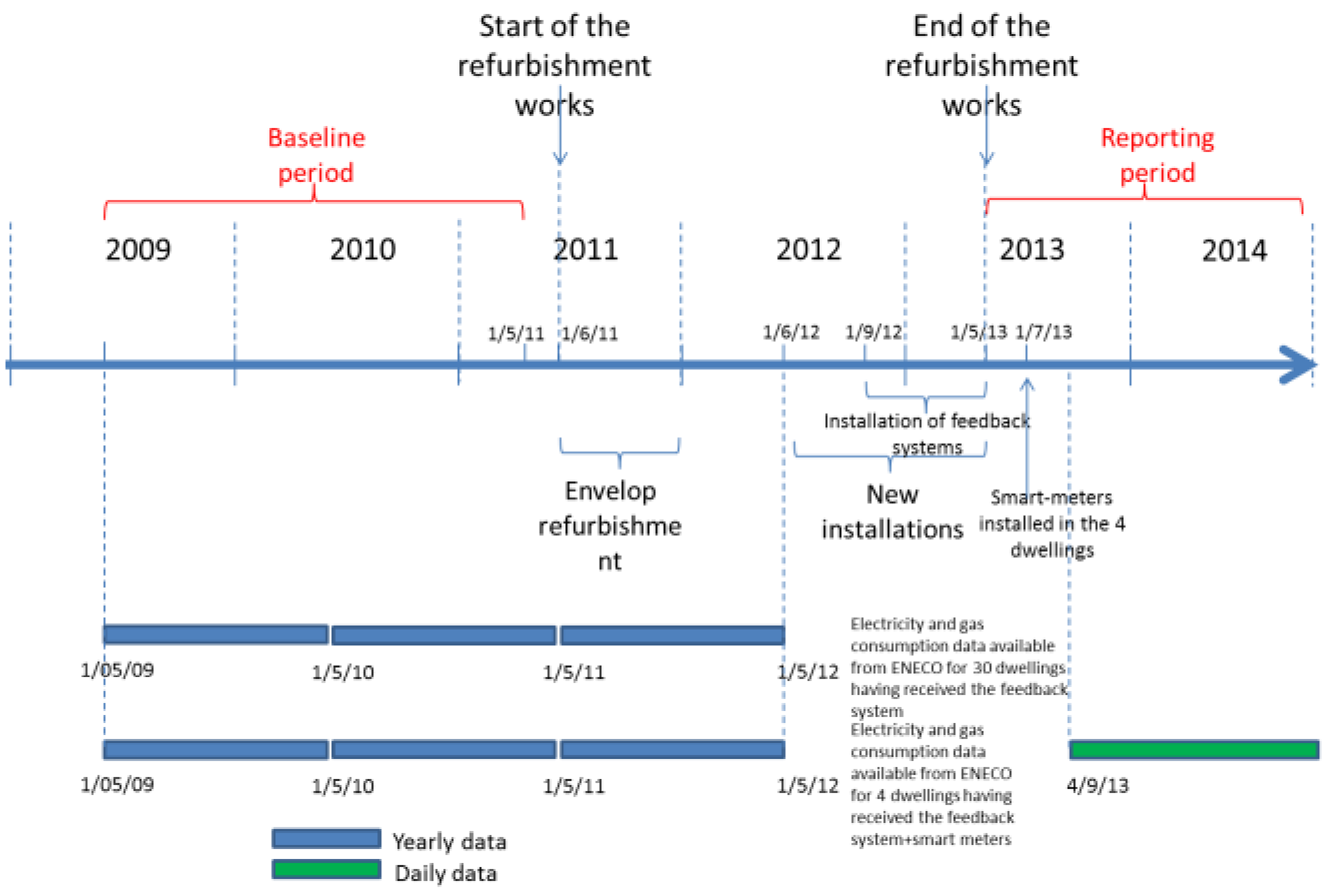


Figure 28: General Timeline of the measures performed in Delft including the smart meter installation

The full list of the monitored dwellings is the following:

Type	#	m²/dwelling
Floor apartments	40	79
Top apartments	20	88
Top apartments (semi att.)	20	76
One family house (semi att.)	14	96
One family house (att.)	14	96
Total	108	

Table 22: Number and types of dwellings involved in the BEEM-UP project

2.1.2 Data adjustment

The actual energy data have to be corrected for degree days and for changes in the base temperature (or specific balance point temperature). First, heat requirements are not linear with the outdoor temperatures and second, due to insulation and change of indoor sources, the balance point temperature will change as well. An important consideration is that the impact of insulation in the Delft project is less than calculated, for these reasons:

-small reduction in glazing surface area and change of glazing type, gives loss of solar inmission,

-the insulated roofs border unheated attic space or most often unheated bedrooms,

-subfloor insulation was cancelled.

-the cavity wall improvement including sealing has minor effect.

These characteristics allow for only small correction of the balance point temperature.

Quite important is the change in heating system, from local chimney tied to central. In the reference situation the heater is situated in the living room, giving convective and radiant heat to the persons in these small rooms. Good comfort in one room can be achieved in otherwise cold bedrooms, resulting in low average temperatures of the dwelling. About 70% of dwellings after the renovation have modern central heating with high efficiency heaters, situated in a closet. After the renovation, the living room is heated with radiators that produce more convective heat and less radiant heat, while the distribution system distributes relatively more heat to other rooms. The effect is a higher indoor temperature and lower balance point temperature.

Finally, how to correct for the fact that heat requirements are not linear with outdoor temperature? First, in extreme cold weather the average indoor temperature lowers due to unheated bedrooms, while occupants adapt their needs and put on warmer clothing, resulting in even lower average indoor temperature. Also, the efficiency of heaters changes: highly efficient heaters perform better due to lower return temperatures, but traditional (atmospheric) heaters tend to perform a little worse. Before the renovation cold weather led to lower efficiency and after the renovation to better efficiency. In warm winter periods the opposite effect on efficiency is found. Taking these effects into account, the following corrected degree days were used in the calculations, which indicate minor changes, lower than could be reasonable.

Period	Degree days applied	Degree days October -May Balance point 15,5°C outdoors, 16,5°C indoors **before** renovation	Degree days October-May. Balance point 15°C outdoors, 17,5°C indoors **after** renovation	APPLIED CORRECTION FACTOR
	Degree Days for reference year 1964-1965 De Bilt **2620**	Degree days for Rotterdam (nearest weather station)		Degree days for reference year in De Bilt: **2620**
2009-2010	3000	2504		1,046
2010-2011	2897	2405		1,09
2011-2012	2718	2188	2412	1,14
2012-2013	3147		2861	0,9156
2013-2014	2430		2155	1,215

Table 23: Degree days and correction factors used for the Delft site

The degree-day correction factor for 2013-2014 is high: factor 1,215. In a warm winter the energy use is higher than the degree days suggest, meaning that the correction is too much. A smaller reduction of the correction factor than theoretical degree-day correction would be better.

2.2 Data available

The data available for the baseline and the reporting periods are synthetized in Table 24.
Data were collected by:

- energy meter readings for all apartments in the project, consumption per year over the period June 2009 up to June 2014;
- interviews during house visits with 31 households in May 2014;
- detailed monitoring data (hourly) of four dwellings;
- interaction with a group of people active during the renovation and focussing on better community involvement and energy consciousness as by-product of the renovation.

Initially, the data from the meter readings were not available per single household for privacy reasons. Clusters of addresses had to be made to avoid individual consumption recognition. The first analysis was done on the basis of data from the main energy provider and BEEM-UP partner ENECO. However, due to a free energy distribution market, not all tenants take energy from ENECO. After the first analysis some questions arose on the reliability of data that were submitted by the tenants. The energy network organisation STEDIN who is responsible for all energy meters gave detailed information on all consumption data over a five year period. These data could be corrected according to several criteria that improved the reliability of energy data considerably:

- omitting data from people who moved out, resulting in “incomplete” years;
- omitting data not based on actual meter reading, but on statistical “predictions”;
- taking away outliers in the low consumption range: negative consumption, less than 100 m3 gas per year, implying that these dwellings were hardly occupied.

These corrections resulted in omission of half of all the consumption data, relatively more data in the reference period and the best data in 2013-2014. However 90 out of 108 dwellings are still in the data set with more or less complete energy meter readings, the best for electricity. Of in total 79 households reliable information is available about the heating energy demand in the reference situation and of 86 households in the post-renovation period. The meter readings are submitted by the tenants while inspectors from the energy network organization STEDIN check the meter-readings every three years. No difference could be made between the data provided by tenants and these inspectors, however.

	Baseline period (before refurbishment)			
Available data	**Data available at dwelling level/Building level**	**Acquisition frequency**	**Provider of the data**	**Period of measurement**
Gas consumption	Data available for 31 dwellings that will have solar boiler in 2012	Annual (at moment of billing)	STEDIN	June 2009 – May 2010, June 2010 – May 2011
	Real Data available for 79 dwellings all together	Annual (at moment of billing)	STEDIN	June 2009 – May 2010, June 2010 – May 2011
Electricity consumption (low and high tariffs separately)	Data available for 82 dwellings	Annual (at moment of billing)	STEDIN	June 2009 – May 2010, June 2010 – May 2011
	Data available for 82 dwellings	Annual (at moment of billing)	STEDIN	June 2009 – May 2010, June 2010 – May 2011
	Reporting period (after refurbishment)			
Available data	**Data available at dwelling level/Building level**	**Acquisition frequency**	**Provider of the data**	**Period of measurement**
Gas consumption	Data available for 31 dwellings having been equipped with solar boiler	Yearly (from May to May)	STEDIN	June2011–May2012, June2012–May2013, June2013–May2014
	Data available for 86 dwellings	Yearly	STEDIN	June2011–May2012, June2012–May2013, June2013–May2014
	Data available for 4 dwellings	Daily	ENECO	From 01/10/2013 to the end of the BEEM-UP project
Electricity consumption (low and high tariffs separately)	Data available for 31 dwellings having been equipped with solar boiler	Yearly (from May to May)	STEDIN	June2011–May2012, June2012–May2013, June2013–May2014
	Real data available for 90 dwellings	Yearly	STEDIN	June2011–May2012, June2012–May2013, June2013–May2014
	Data available for 4 dwellings	Daily	ENECO	From 01/10/2013 to the end of the BEEM-UP project

Table 24: Data available for the periods before and after refurbishment for Delft site

2.3 Analysis of final results

For the Delft site, the monitoring data are analyzed at dwellings level since all dwellings are individually metered for natural gas and electricity. There is no metering at block level. It is not possible to measure the blocks because all the dwellings have individual energy contracts.
The data in the graphs always refers to the consumption until May in a given year (2014 consumption is therefore from June 2013 until May 2014).

Figure 29 and Figure 30 are based on all apartments and dwellings after deleting incomplete years and all calculated (instead of metered) data. Only 50% of all consumption data can be used according to these criteria.
The overall energy savings for heating are 35% over two years after the renovation and 38% considering only the last year. The heating energy use changed from 140 kWh/m^2·year to 88 kWh/m^2·year.

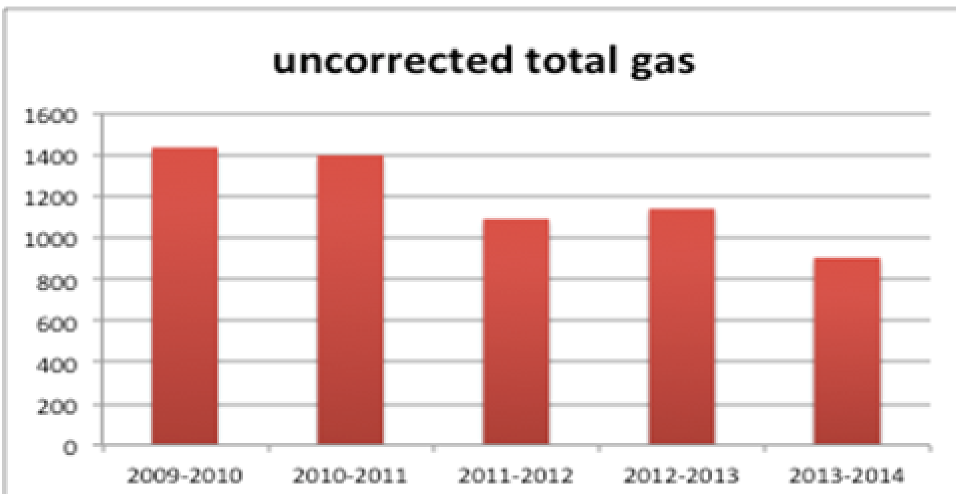


Figure 29: Non-corrected gas consumption (m^3) for heating, hot water and cooking

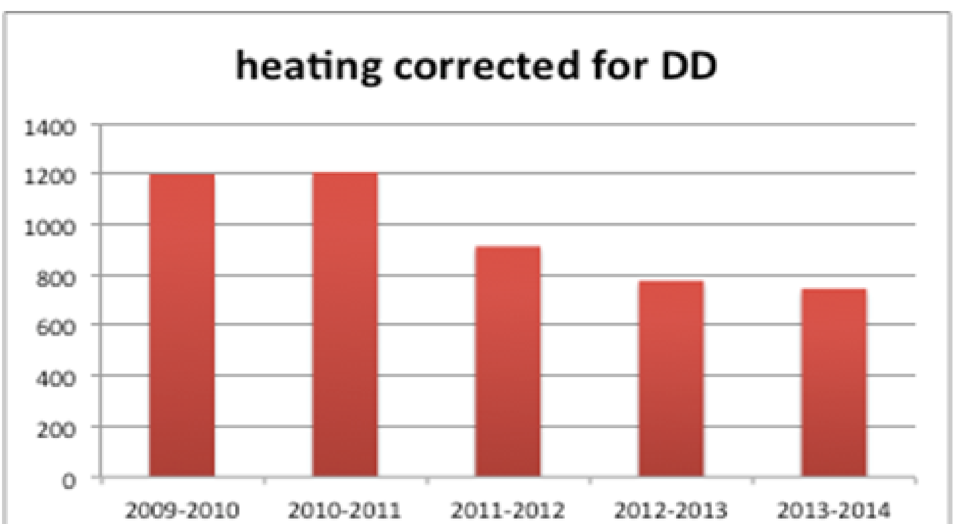


Figure 30: Corrected gas consumption (m^3) for all dwellings (n=90)

Figure 31 show the electricity use over a period of 5 years. The electricity consumption is 30.8 kWh/m^2·year before and 29.6 kWh/m^2·year after the renovation. The electricity use reduced some 4%.

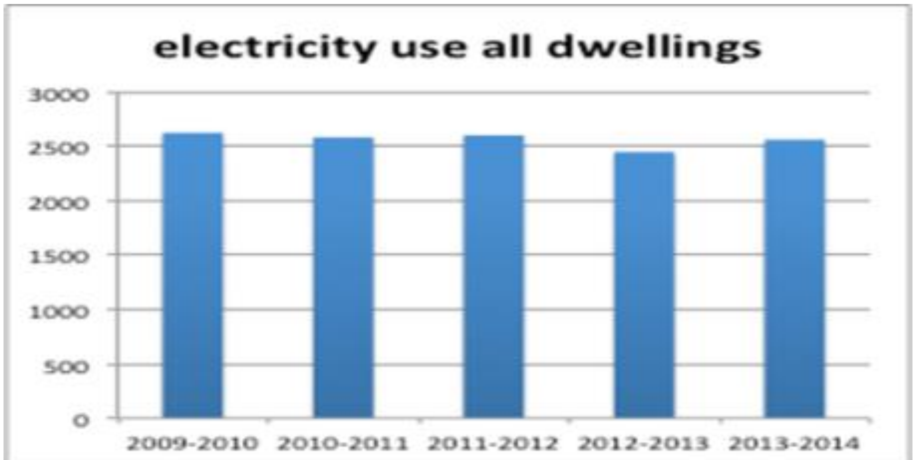


Figure 31: Electricity meter readings (kWh) over a five year period

The average electricity use for households in The Netherlands is 3500 kWh. The average natural gas consumption is 1600 m^3. Actual energy use in the project in Delft is much lower: 30% lower than average for electricity and 32% lower for gas.

2.3.1 Heating

The envelope was refurbished in 2011. Solar collectors were effectively installed after the summer of 2012 and feedback systems were installed in 2013 (see Figure 28).

Different dwelling types have slightly different energy saving measures. All dwellings have new windows. Semi-detached dwellings and maisonettes on the higher level have roof insulation. Other measures depend on the choice of the tenants: new heater, central heating, combined system for domestic hot water, solar domestic hot water system, and home energy management system. Only two dwellings have floor insulation, not because this “free selective” was not chosen by the tenants, but because of discovery of old asbestos flooring material in some apartments, that is left as it is. Potentially, the apartments under a roof and the semi-detached dwellings can have the maximum package of measures. Dwellings with this maximum package were selected from the data set, to find the actual energy savings for this package.
The effect of singular measures can be studied, but the results are based on low numbers per set of variables. Nevertheless, a table with effects per measure is produced with most likely contributions.
As explained in section 2.1.2, the degree-day correction factor for 2013-2014 is high: factor 1,215. In a warm winter the energy use is higher than the degree days suggest, meaning that the correction is too much. A smaller reduction of the correction factor than theoretical degree-day correction is suggested. Figure 32 shows the gas consumption corrected with official factor as well as two/thirds of degree day correction factors. The energy efficiency improves with 40%. The energy use drops from 137 to 82 kWh/m^2·year

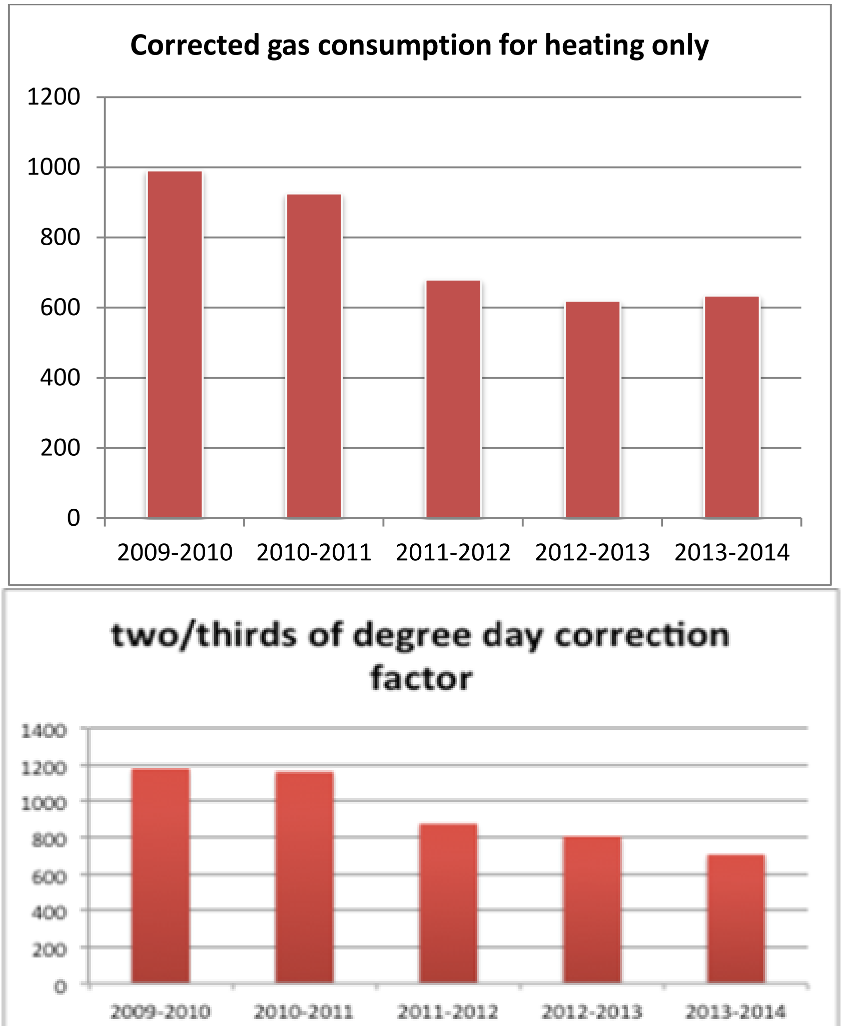


Figure 32: "New" corrected gas consumption (m^3) for heating in Delft project

Figure 33 presents the heating energy consumption in m^3 natural gas for the top level maisonettes with traditional central heating, new windows and roof insulation. Dwellings with traditional central heating did not change the heating system, implying that the figure presents the effect of insulation measures only. The effect of insulation starts at the end of 2011 and is visible in the figure. In this small sample the energy savings related to heating use are 36 % (from 105 kWh/m^2·year to 70 kWh/m^2·year).

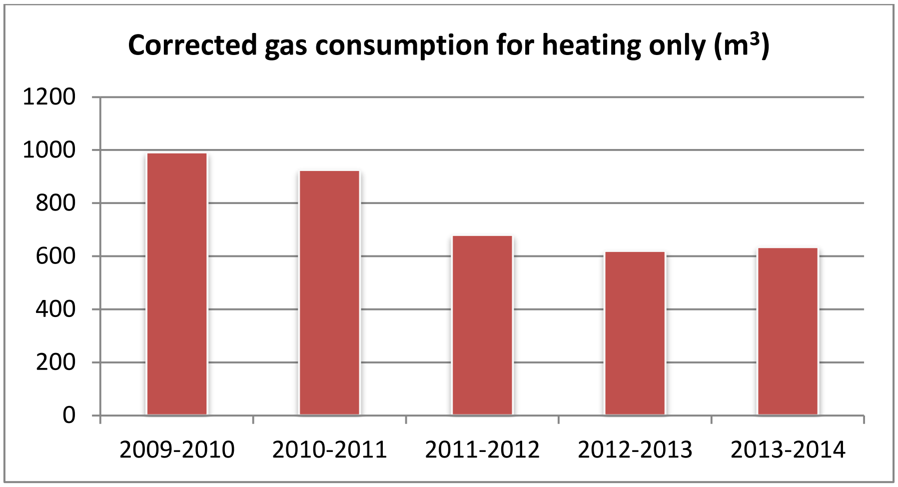


Figure 33: Corrected gas consumption for heating only for the top apartments with traditional heaters

Figure 34 gives the gas consumption for heating only for dwellings with high efficient heater, TOON and solar thermal system.

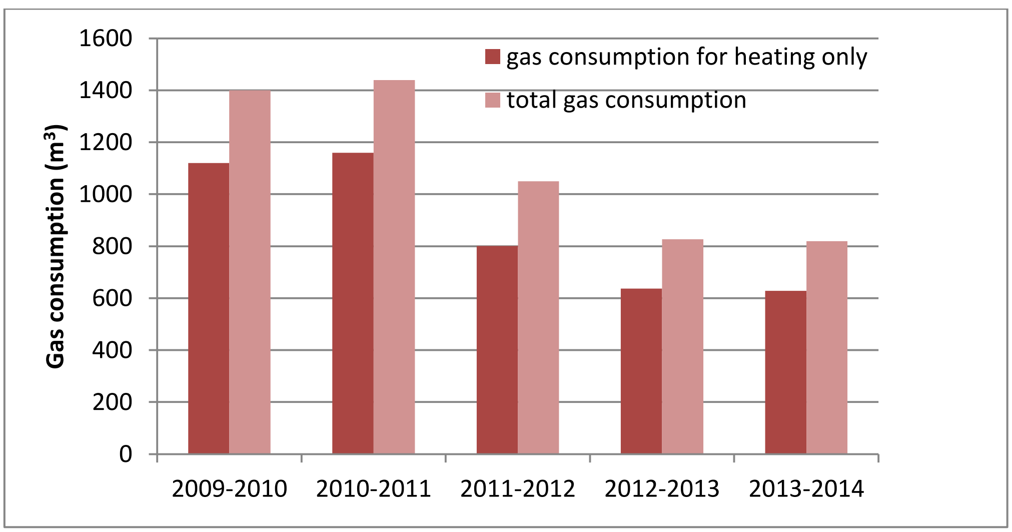


Figure 34: Gas consumption (m^3) for heating only and total in dwellings with high efficient heater, TOON and solar thermal system (not for heating)

The dwellings presented in Figure 34 (n=7) indicate a reduction from 1420 to 815 m^3 gas per year, which is 43% energy savings.

Most of these dwellings changed from heating with traditional heaters to high efficient gas heaters and more comfort for hot water: from 2.5 to 6 dm^3/minute of hot water for showering and kitchen use. The rebound effect for this improved comfort is at least 50 m^3 of gas use per year. The rebound effect for the central heating system is relatively low, considering the results of interviews.

Figure 35 shows the gas consumption for dwellings with high efficient heater and Toon system. The savings are 45%, energy drops from 130 to 72 kWh/m^2.year. The effect of the new heater and TOON are therefore positive.

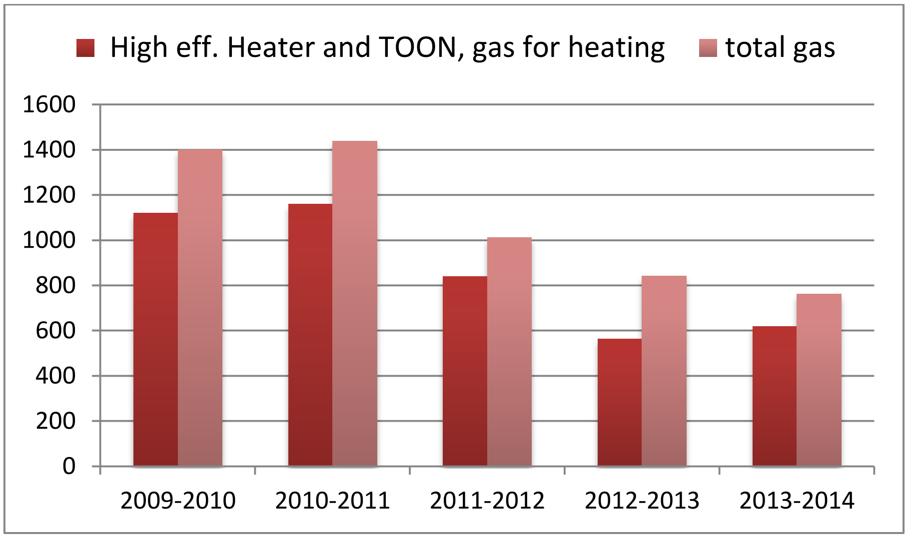


Figure 35: Gas consumption for heating and total gas consumption with high efficient heater and home energy management system

As shown on Figure 36, savings as effect of heaters is the same (or little more) than including TOON: in these dwellings the energy savings are 48%, and drop from 102 to 53 kWh/m^2.year.

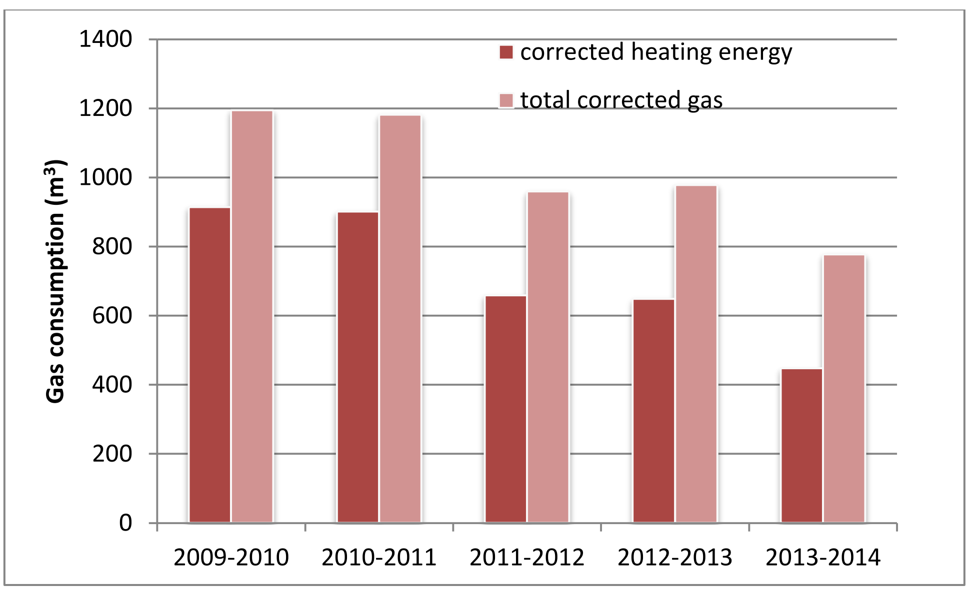


Figure 36: Effect of high efficient heaters - Gas consumption for heating only and total in dwellings with high efficient heater

The effect of the different measures are shown on the following graphs.

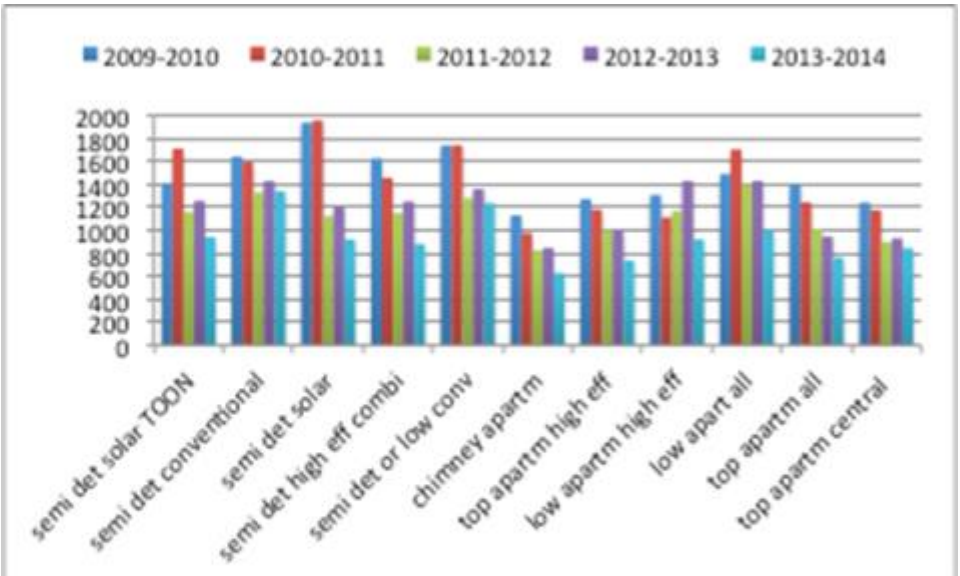


Figure 37: Effect of different measures, uncorrected for degree days and energy for hot water and cooking

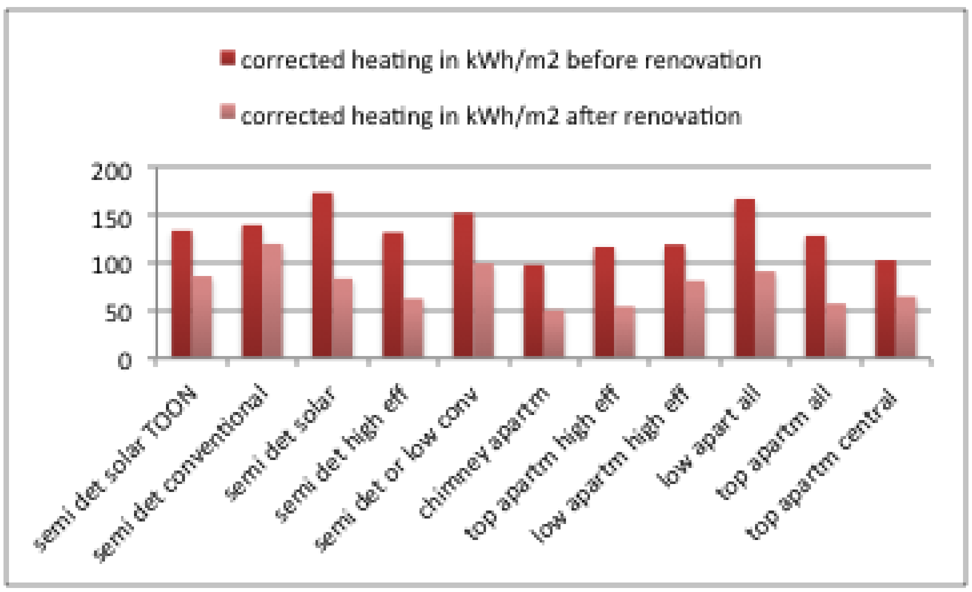


Figure 38: Effect of different measures on heating consumptions

Table 25 gives the corrected energy consumption for heating in kWh/m².year for clusters of dwellings. The clusters were formed to avoid privacy violation.

The effect of insulation depends on the dwelling type and ranges from about 17 -37%. The best results are obtained in top apartments, where roof insulation borders heated rooms: the effect of insulation of that envelope is 37%. Where the heating system is changed into high efficient central heating, the savings sum up to from 35% to 50%. The next great effect comes from solar domestic hot water. 12 apartments have these measures. The energy savings for heating are 55% (Figure 39).

Heating consumption (kWh/m².year)	Before renovation	After renovation	Savings %
Semi-detached high eff. solar +TOON	134	86	36
Semi-detached conventional + geyser	140	120	14
Semi-detached high eff. solar	173	84	52
Semi-detached high eff combi	132	62	53
Semi-detached or low level apartments with conventional central heating	152	100	35
Apartments with chimney tied heater	98	50	48
Top apartments with high efficient heater	117	54	54
Low apartments high efficient heater	119	81	32
Low apart high eff. solar and TOON	167	91	45
Top apartment with high eff. solar and TOON	128	57	55
Top apartment with central heating convent.	103	65	37

Table 25: Corrected energy consumption for heating in kWh/m^2.year for clusters of dwellings

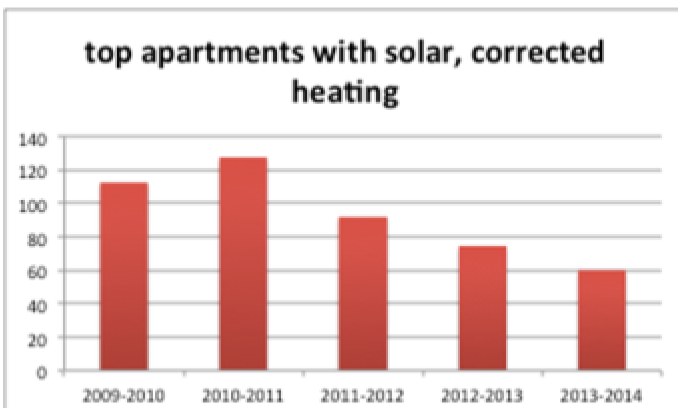


Figure 39: The best savings effect in top level apartments with solar systems and high efficient heater: from 128 to 57 kWh/m².year

Th effect of different measures after correction for hot water, cooking, cleaning and corrected for degree days (for heating only) are provided in the figure below. In this figure the corrections for hot water are based on the before and after situation: before: geyser, after high efficient heater, in many cases including solar system.

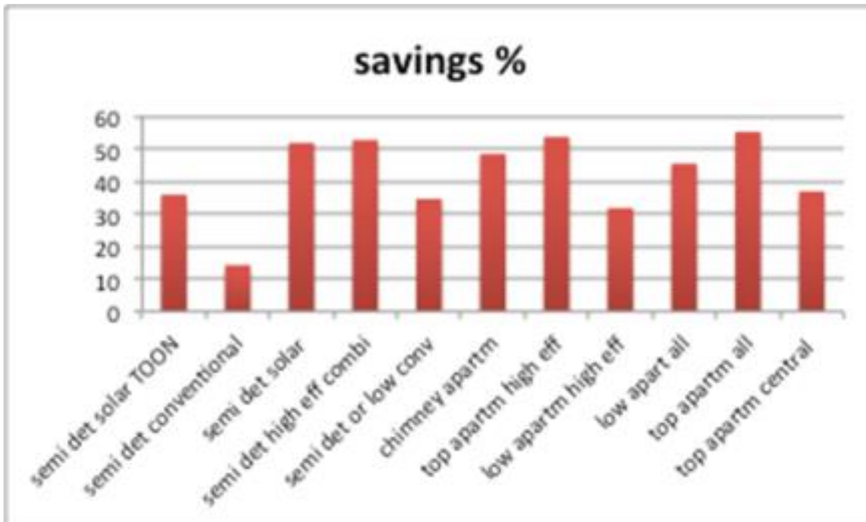


Figure 40: Effect of different measures after correction for hot water, cooking, cleaning and corrected for degree days: heating only

The table below summarizes the results obtained. The effect of the new heater is positive, even considering the rebound effect of more hot water. The effect of the solar system, which is always in combination with high efficiency heater, is quite positive.

Heating (kWh/m²·year)	Semi detached	Apartment low levels	Apartment high levels
Reference	145	145	120
Insulated envelope	120	100	75
+ high efficient heater	90	90	60
+ high efficient heater + solar domestic hot water	90	90	60
+ high efficient heater + solar domestic + TOON	85	85	55
Savings complete package	**41%**	**41%**	**54%**

Table 26: Summary of heating energy savings results obtained for the Delft site according to the implemented measures

2.3.2 Electricity

Figure 41 on electricity usage shows that the electricity usage is under the Dutch average level, which is 3500 kWh per year. Since the TOON was installed in 2013, we can conclude that it was ordered by a group of people with a higher electricity use. Both sources of data suggest that the feedback system causes about 7% reduction in electricity use in 2014.

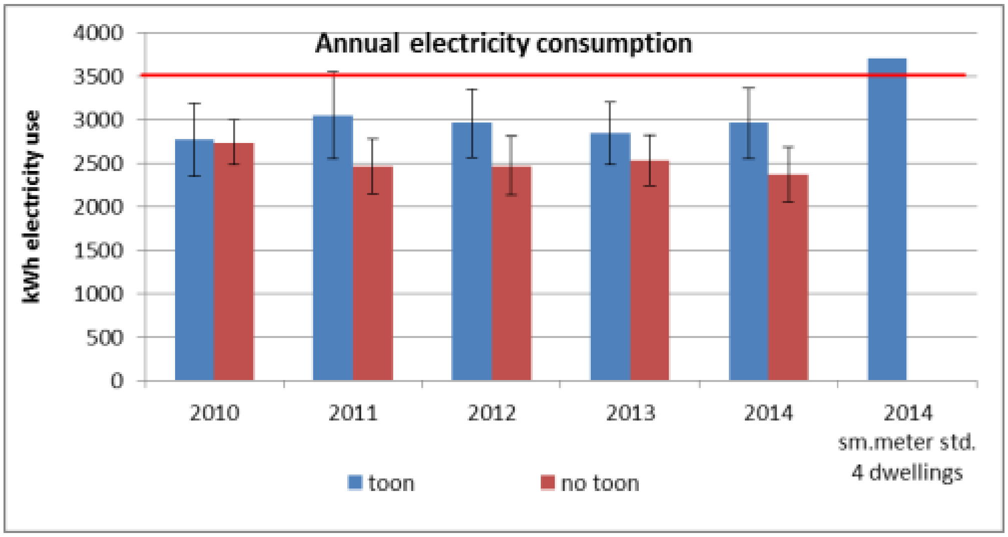


Figure 41: Electricity consumptions obtained for the dwellings with and without feedback systems - baseline till 2013, 2014 with Toon

The graph below shows a higher electricity usage by the users of a high efficiency gas boiler (>83%). Since the heating is in both groups done by gas, the difference between electricity use in these two groups can only indirectly be related to the heating system (we could for example speculate that high efficiency boilers are present in dwellings with a higher income, where also electricity use is higher due to more appliances present in such a household).

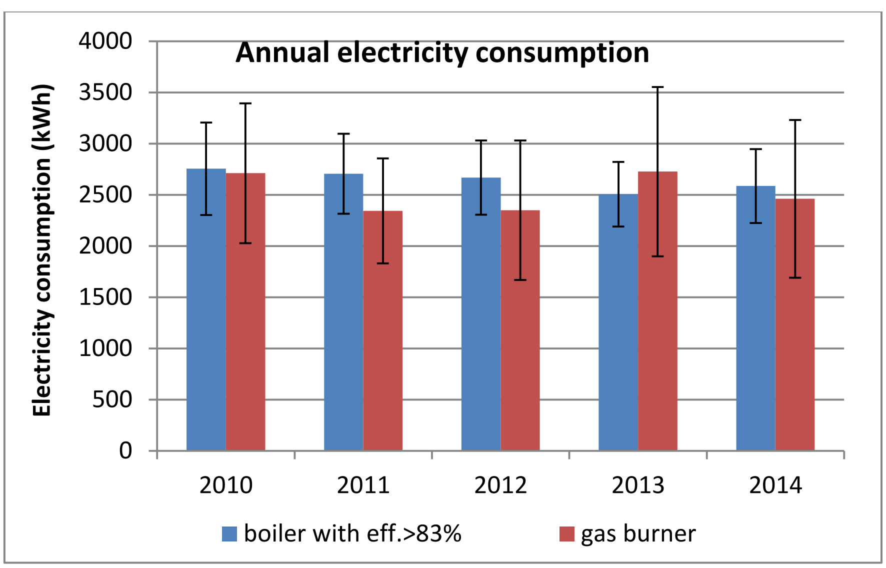


Figure 42: Electricity consumptions obtained for the dwellings with different heating systems

The solar collectors have an electrical water pump which is most likely the cause of the higher electricity use in Figure 43. The consumption of this pump seems to be about 500kWh per year, which is not negligible.

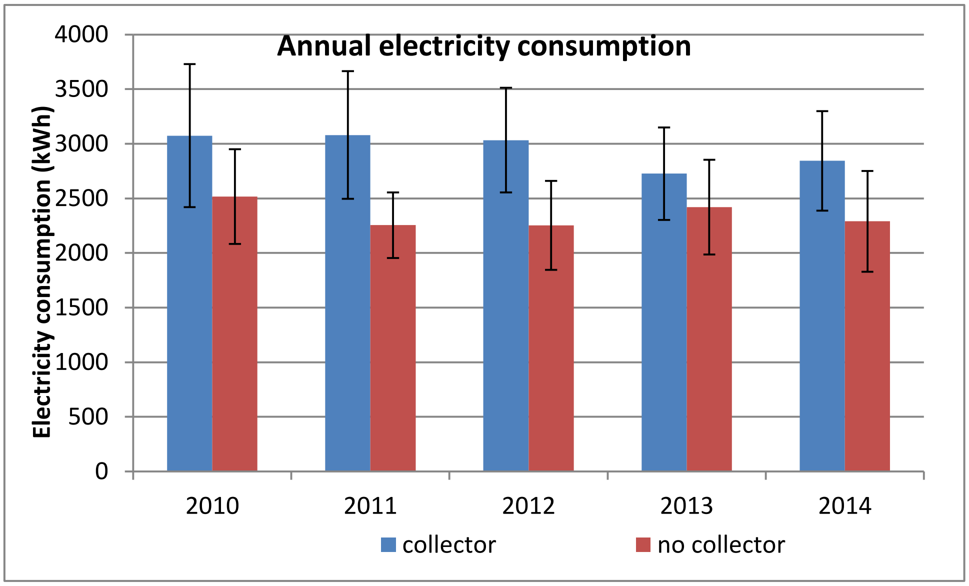


Figure 43: Electricity consumptions obtained for the dwellings with or without solar water collectors

Therefore a mitigated result is obtained for electricity consumption for Delft site.

2.3.3 Complementary results obtained from the interviews conducted with the tenants

A post-occupancy analysis has been conducted with interviews in Delft [7].

General information about tenants' satisfaction has also been collected through the interviews. As a general rule, the users are very satisfied about:

- Higher indoor temperatures that leads to a better comfort,
- More bedrooms heated (not more overheating in the summer),
- Better windows, vents and less draught,
- The energy awareness effect of TOON,
- The process of the renovation.

But there are still some items which are source of dissatisfaction:

- Poor acoustic insulation (neighbours upstairs),
- Poor maintenance of technical installations after breakdown.

Heating use

Figure 44 shows the corrected gas consumption used for heating over 5 years based on 26 interviews that could be matched with energy data from STEDIN (about 35% of savings are achieved). Of the 31 households only 26 provided gas consumption data, some were not based on meter readings but based on statistics by the energy company; energy data of 5 interviewed households were deleted from the analysis.

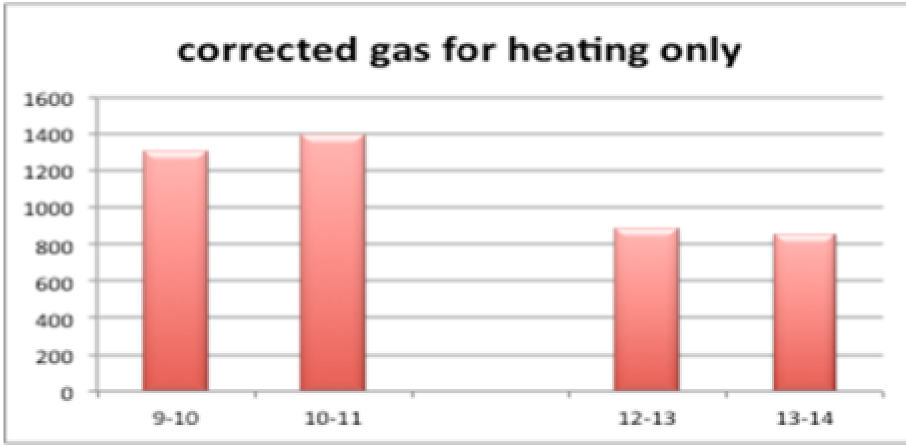


Figure 44: Degree day and balance point corrected gas use for space heating of 26 interviewed households, resulting in 35% savings

Electricity use

The electricity consumption can change on the basis of changes in the household, but also because of new installations: the pump energy for solar domestic hot water and for central heating, the stand-by energy use of the home energy management system.

The electricity consumption trend is rather stable as shown on Figure 45. More electrical appliances, such as battery chargers, tablets and other computers, coffee machines and larger refrigerators are used, but the efficiency improves. New TV-sets tend to be much larger than the previous ones and some are in use for a longer period per day, due to abandoning cable-connections for Internet. Cable provides radio directly, but for Internet based radio services the connection box must be in operation. Higher efficiency may compensate longer period of use. Further electricity savings come from LED lighting. Many households only use a few lights for permanent lighting and most often with energy efficient fixtures. The lights in the toilet, the hall and bedrooms are used for short moments. It means that lighting has little impact on the total electricity consumption.

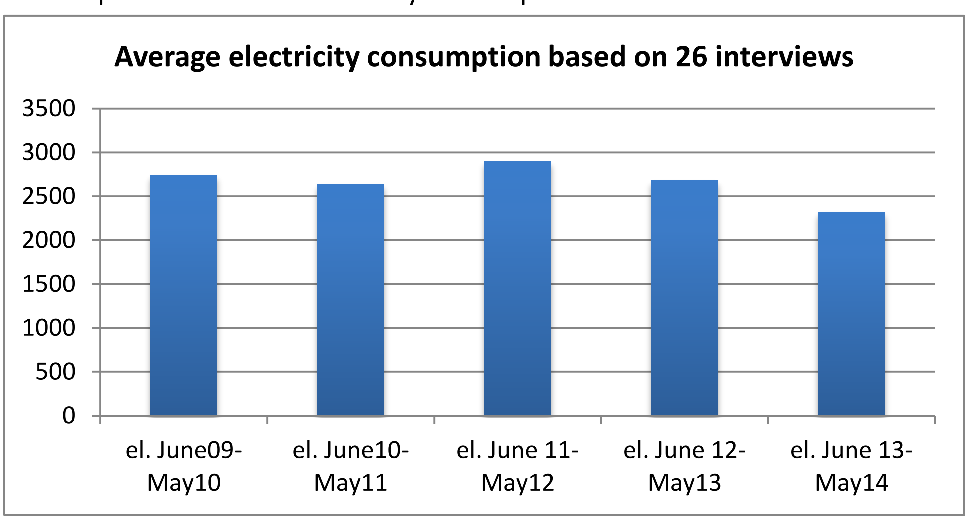


Figure 45: Average electricity consumption over five years of 26 interviewed households

The electricity consumption for this small selection of households seems stable, except for higher level in 2011-2012 and lower level in 2013-2014. The higher electricity use during the renovation may come from two periods with scaffolding blocking the light and requiring more electric lighting and even more heating due to reduced influx of passive solar energy. A comparison with sun-hours and 2009-2010 (1106) and 2013-2014 (1043) did not give an explanation for the lower level in 2013-2014, nor did fine-tuning of the number of sun hours for shorter periods (spring time) (www.zonurencalculator.nl).

Hot water use

The number of showers is 5.8 per person per week. With the traditional geyser and an average of 14 showers per household, the energy use is 185 m^3/year or 21.5 kWh/m^2.year. With the modern central heating system the water flow increases and the energy use for showers rise to 285 m^3/year, or 33 kWh/m^2.year despite a better efficiency of the heater. The rebound effect for hot water is about 100 m^3 for households with average shower frequency and that changed from geyser to combined heater. The solar system compensates this and improves the gas consumption with 145 m^3: from 285-145 = 140 compared to 185 m^3 with geyser. The solar system saves more than 50% of domestic hot water energy use, but the savings are 185-140 = 25% compared to the "energy conscious" use of the geyser, in other words compared to the reference situation. For the households who had a combined heater with traditional efficiency already before the renovation, the savings effect is higher: 315 before to 140 m^3 per year after the installation of the solar domestic system, or 55% savings on energy use for domestic hot water.

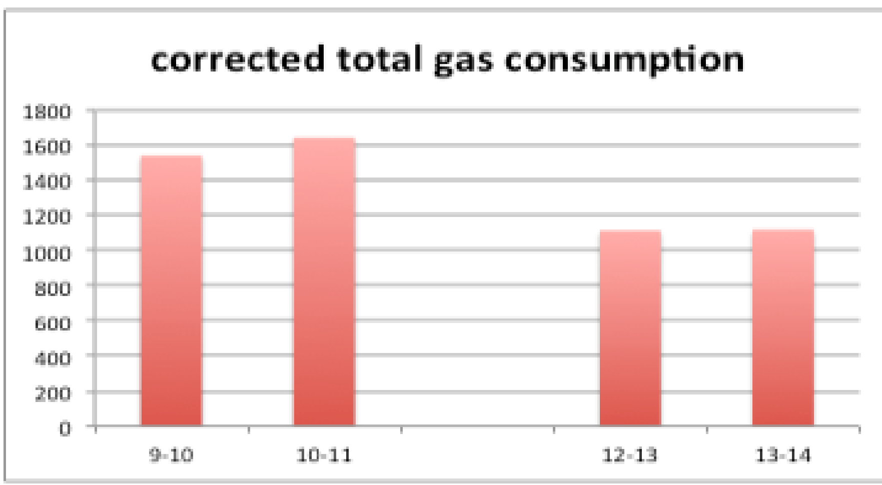


Figure 46: Total gas consumption before and after the renovation in 26 interviewed households. The energy savings are 30%.

2.4 Conclusions for Delft site

Table 27 summarizes the main results obtained in terms of energy savings and provide a comparison with the predictions and the general objectives of the project.

In WP1 calculations were done to determine the theoretical energy performance of the building before and after refurbishment. The calculations were conducted using an operative temperature of the buildings of 20°C.

The contribution of different measures to energy savings is different from theoretical models. The contribution of insulation measures is rather disappointing in practice, which is caused by the relatively low improvement in insulation value of the facades including windows, while the roof has low impact on heat losses, because it covers bedrooms that are not heated or atticks that already function as an important temperature buffer.
The effect of solar domestic hot water systems and heaters with high efficiency is positive. The number of showers is 14 per week on average and the solar thermal system can save 50% of the energy use for hot water. When changing from small geysers with 2,5 dm^3/minute hot water flow to 6 dm^3/min with the new installations, the solar system compensates for this higher comfort level and even more, meaning that the solar system covers the rebound effect and even saves energy in practice, but for the overal energy use in the project the savings are negative: more energy for domestic hot water.
The effect of high efficient heaters is positive, especially when replacing traditional central heating. But the impact of the “efficiency factor” is not what counts, rather the side effects of the closed combustion system, the missing pilot flame. The temperature control is less efficient, while in the future new tenants may change the function of rooms,because the central heating systems supports other functions than sleeping.
These findings do not come from the data anlysis alone. Learning to know the tenants in how they use the dwellings and how they perceive the comfort is very important.

The energy focus of the renovation has not met its theoretical promises. On average half of the ambitions have been reached. The gap between theory and practice is being recognized as the main cause. Beginning with the energy consumption in practice and making plans based on user behavior is accepted as a major innovation in renovation, at least among the BEEM-Up partners.

The reasons for not meeting the ambitions in the Delft can be based on both the limits of calculation methods and also based on user behavior.

First, when the energy use is lower than calculated, the savings are lower as well. As for the percentage: it is harder to save on energy when the consumption is low already, even expressed as a percentage of the reference situation.
Second, the improvement of the insulation value of the envelope is quite modest and does not change the heating habits. For the envelope to have effect, a much higher thermal resistance and sealing is needed, with side effects such as the need for balanced flow ventilation. In the Delft project, renovation led to up-to date performance of the envelope, but the improvement of the heating zone, which is the living room and kitchen, is minimal.
The improvements of the technical installations have side effects. The heat production efficiency is higher, but the comfort level as well, which reduces the effect in practice. The solar hot water system is an example: savings are reached, but the effect is reduced by the rebound effect.
The main conclusion is that dwellings with sober installations before the renovation will not save much energy with modern installations that provide much more comfort.
Positive considerations from the Delft project are the involvement of the service provider for the technical installations including TOON. Also the involvement of the tenants has had a positive impact on the quality of the community and the acceptance of the renovation turmoil.
Not paying a rent increase for the sitting tenants has eased the process. It is difficult to evaluate what would have happened with higher ambitions including rent increase, but it could have worked out, if more time would be available for the process.

The fact that a real estate expert claimed that the investments would not increase the sales value and the financial limits of the housing association had great impact on the planning, with the poor results we found. Also, moving the renovation from regular maintenance experts to a temporary work team with expertise in these projects has not been positive for reaching the ambitions including integrating the community development.
Time constraints with regards to the promise to have new windows before the end of 2011 had great impact on the execution.

Looking at the final result, we can conclude that taking the rebound effects into account, the renovation package in Delft leads to 50% energy savings, compared to 75% in theory. However, because not all tenants took the maximum package, the overall savings are one third of the energy use compared to the reference before the renovation. These savings effects have been realized with relatively minor measures and low impact for the tenants, which is a positive result.

Further explanation for the discrepancy could be that the predictions do not fully correspond to what has been really implemented on site in terms of refurbishment. Main differences are in the wall insulation quality and missing floor insulation.
The simulations hypotheses are slightly different from the real parameters of the Dutch site. And this could be identified at several levels:

- air exchange rates through window ventilation can be different from figures used in the calculations,
- the efficiency of old boilers (before renovation) used for the simulations was based on estimated figures therefore calculation of data relative to the baseline period can be distorted.

Another explanation for this discrepancy could concern the temperature set-point used by the tenants and that could be different than the one used for the simulation (the temperature set point used for the predictions calculation was 20°C for Delft). This could lead to a very different result. It is commonly admitted that decreasing heating temperature by 1°C could lead to 7% energy savings in return. The average temperature of living/bedrooms and circulation spaces before the renovation is more likely in the range of 12-13^{o}C than 20^{o}C. It is quite obvious that this temperature level improved. A change of 2^{o}C in practice, but not in the calculations.

Moreover, the calculations were made considering that the whole building was heated, not only one room. Nevertheless before refurbishment, the tenants would heat one single room mostly. Therefore the consumption was not very high before refurbishment. In any case it was much lower than for a dwelling where all rooms could be heated. However, this level of comfort should not be assumed for healthy living/ future living where adequate comfort conditions need to be provided. And these conditions have been apparently reached thanks to the refurbishment according to the positive comments from the tenants collected during the interviews about the comfort conditions.

Therefore, the simulations hypotheses are different from the real implementation that has been conducted on the Dutch site and this could explain the discrepancies observed between simulations and measurements.

OTB and Woonbron have done qualitative research to look deeper into the user aspects. The results of that are presented in deliverable D3.6. 30% of the tenants have been interviewed. The overall opinion is that they are quite satisfied with the improved comfort level. The qualitative and very positive results obtained in term of tenants' satisfaction related to comfort should therefore be emphasized and put forward regarding the benefits from the refurbishment process.

Recommendations

The renovation practice must focus more on insulation to obtain better than moderate results. The cool bedrooms can be welcomed, but if the layout of the central heating would support two zones of heating, more energy could have been saved. The natural ventilation can be energy efficient, considering avoiding electricity use for fans and the embedded energy of installation and maintenance, but for real low-energy dwellings heat recovery ventilation is welcomed for the few winter months. A solar thermal system is welcome as well as part of the package and a large grid-connected PV area.

Dutch site	Metered*			Simulated**			Target
	Baseline period measurements (STEDIN data)	Reporting period measurements (STEDIN data)	Savings achieved (%)	Predicted performance before refurbishment (WP1)	Predicted performance after refurbishment (WP1)	Savings according to predicted performances	Objectives of the project in terms of energy savings
	kWh/m².year	kWh/m².year	%	kWh/m².year	kWh/m².year		%
Heating only (degree day adjusted)	137	75	45	314.2	91.9	71	**75**
Domestic hot water	21.5	33	-53	19.9	9.6	52	**45**
with solar system after renovation	21.5	16.2	24.6				
Electricity	32.4	30.2	0	11.8 (for lighting only)	8.5 (for lighting only)	28 (for lighting only)	**42** (for lighting only)

* This metered data is for dwellings which are renovated to different energy efficiency levels (not all have received the full package).
** This data was simulated for the whole package.

Table 27: Comparison between predicted performances and the measurements and energy savings evaluation for the Dutch site

Chapter 3 Final reporting of monitoring results for the site of Paris

3.1 Main characteristics of the pilot site and reminder on the methodology used

3.1.1 Main characteristics of the pilot site and reminder on the refurbishment

The BEEM-UP demonstration in Paris, France is a complete refurbishment of a building located in the center of Paris, 800 m from Montparnasse train station, at the corner of Rue Cotentin and Rue Falguière (2 addresses for one building). It is composed of 87 dwellings distributed over 8 levels in one building, and it was built around 1950. In 1993, the building was renovated (outer insulation, double glazed windows, boilers), but it needs a major upgrade to become a pilot for bringing ICF' housing park to the low energy standard for renovated buildings.

Key indicators of the pilot site	Value for the French pilot site
Location	Paris (France)
Year of construction	1958
Surface retrofitted	4352 m² living area
Number of dwellings	87
Owner/partner	ICF Habitat Novedis
Level of intervention	Deep renovation (tenants not evacuated during retrofitting)
Total investment	4.251.000€ excl. VAT

Table 28: Key indicators related to the French pilot site

a)

b) 

Figure 47: Pilot site in Paris

a) Façade view of the building in Paris before refurbishment
b) Façade view of the building in Paris after the refurbishment

The improvement measures for the site of Paris are summarized in the table below:

Envelope	Thermal insulation of facades, roof, basement ceilings and balconies Walls street side: + 20cm ETICS EPS λ032 / Walls back side : New 20cm EPS ETICS λ032 / Basement: + 10 cm insulation EPS λ032 below ceiling / Roof: New 10cm insulation PUR λ024 on ceiling
Windows	Replacement of windows and apartment doors New PVC double glazing, U= 1,5 W/m².K
Heating (source and distribution)	New condensing boilers for heating and warm water (fossil gas) Replacement of floor heating by radiator. Radiators with individual thermostat to adjust the central heating setpoint.
Domestic hot water	Central system, with a heat pump in combination with sewage heat recovery
Ventilation system	Central system, humidity controlled mechanical exhaust system
Electricity	Electrical renovation of common spaces and non-renovated homes
ICT – energy management (incl. smart meters)	Synco living system, displays in flats; an 11% saving expected. Individual billing of DHW and heating is introduced.
Lighting	All public spaces fitted with low-energy light systems. All tenants encouraged to switch to low-energy lighting.
Renewable Energy Source	Implementation in the basement of a system for grey water heat recovery, Heat recuperation from waste water
Sanitary hot water	Focus on tenant behaviour and awareness-raising during and after retrofit is expected to lead to further reductions in energy consumption.

Table 29: Improvement measures conducted in the site of Paris

3.1.2 Data adjustment

The data collected for the heating consumption in Paris are HDD adjusted (monthly or yearly according to the way the data are displayed).

3.2 Data available

A sample of dwellings has been selected for the monitoring before (17 dwellings) and after renovation (10 dwellings).

3.2.1 Baseline period

For this building, the baseline period has been established through the means of energy bills, plus partial measurements realized on a sample of dwellings (17).
It allows to study some details on the energetic behavior of the building before refurbishment and hence to give better translation of the sources of energy savings.

3.2.1.1 Energy bills collected

The gas consumptions (common boiler) have been evaluated through monthly bills collected for the building heating system via the building owners. These data are available from 25/10/2007 to 24/06/2009 and from January 2010 to the end of the BEEM-UP project (October 2014).

3.2.1.2 Measurements realized

- General electricity consumption per dwelling, for 17 dwellings, from February 2012 to September 2012,
- Electricity consumption for DHW production, for 17 dwellings, from February 2012 to June 2012,
- Electricity consumption for lighting, for 17 dwellings, from February 2012 to June 2012,
- Comfort parameters: indoor temperature and relative humidity for 17 dwellings, from February 2012 to June 2012.

Annex 1 gives the list of the dwellings that have been equipped with monitoring devices during the baseline period. The plan showing the organization of the baseline monitoring deployment is provided in annex 2.

3.2.2 Reporting period

The SYNCO LIVING system[5] was initially sounded out to be used as the main monitoring system able to collect all the data required for the evaluation within the BEEM-UP project after the refurbishment.
The data provided through the SYNCO LIVING system are:

- Heating consumption per dwelling.
- Hot water consumption per dwelling.
- Electricity consumption per dwelling.
- Indoor temperature per dwelling (get through the regulation system).

[5] SIEMENS product.

However, a delay in the refurbishment works have affected the completion of the installation of the SYNCO LIVING system in time for the BEEM-UP project evaluation. Therefore to get data during the year 2014, some temporary monitoring equipment have been selected and installed on site in a restricted sample of ten dwellings.
The selection of dwellings has been made so as to enable a quick installation and to facilitate an easy monitoring process (focus on the tenants who had agreed to participate and support from an external association Couleurs d'Avenir).
Table 30 below gives the details of the appartments that have been instrumented.

Dwelling number	Type / Surface
121	T3 / 56.5 m²
143	T3+ / 67.2 m²
152	T2 / 39.5 m²
172	T3 / 61.8 m²
212	T2 / 38.3 m²
213	T3 / 55.5 m²
223	T3 / 55.5 m²
232	T2 / 38.3 m²
252	T2 / 38.3 m²
262	T2 / 38.3 m²

Table 30: Synthesis of dwellings equipped in Paris for the period after refurbishment

This temporary instrumentation has been installed at the beginning of February 2014. The general infrastructure (two different radio networks) of the monitoring system installed is provided in Annex 3. It was agreed to use this temporary system until the SYNCO LIVING system is functioning.

Moreover the data related to the functioning of the BIOFLUIDES system has been collected remotely. Several parameters were measured and among them the energy consumed and the energy produced by the system.

3.2.3 Isolated measures

These measurements have been realized in one dwelling before refurbishment in order to be compared with the same measurements after refurbishment:

- **Blower door and Infrared thermography tests**: the objectives of these tests were to detect leakages and insulation faults and determine the leakage rates of a dwelling. Coupling the air leakage tests with Infrared thermography measurements allows for the identification of thermal bridges. These measurements have been performed according to the standard NF EN 13829.
- **Acoustic tests**: the objectives of these tests are to highlight the acoustic insulation defaults between the dwellings. The measurements have been performed according to the standard NF EN ISO 140.4 between two dwellings (Cotentin street) located on the 3rd floor. The data that is analysed is the acoustic insulation between the two dwellings (noticed DnT,A). This value is compared to the same measurement performed after the refurbishment process.

The data available for the baseline and the reporting periods are synthetized in the two tables below.

	Baseline period (before refurbishment)			
Available data	**Data available at dwelling level/Building level**	**Acquisition frequency**	**Provider of the data**	**Period of measurement**
Gas consumption (relative to heating consumption)	Data available at building level	Month (bills)	ICF NOVEDIS	November 2007 to December 2013
Common Electricity consumption (common areas of the building)	Data available at building level	Month (bills)	ICF NOVEDIS	16/12/2011 to 31/12/2013
Electricity consumption (general, DHW, lighting)	Data available for 17 dwellings (but many data are missing because of radio transmission issues)	1 hour	NOBATEK	From February 2012 to June 2012
Comfort parameters: T° and RH%	Data available for 17 dwellings (but many data are missing because of radio transmission issues)	1 hour	NOBATEK	From February 2012 to June 2012.
Envelope performance	Blower door, acoustic and IR thermography tests before refurbishment in one dwelling	Once before refurbishment	NOBATEK	Measured conducted in February 2012
	Reporting period (after refurbishment)			
Available data	**Data available at dwelling level/Building level**	**Acquisition frequency**	**Provider of the data**	**Period of measurement**
Gas consumption (relative to heating and DHW consumption)	Data available at building level	Month (bills)	ICF NOVEDIS	From January 2014 until October 2014
DHW consumption	>Data available at building level >Data available at dwelling level	>Day >Day	>BIOFLUIDES >SIEMENS system	>From 05/11/2014 until December 2014 >From March 2014 until December 2014
Common Electricity consumption (common areas of the building)	Data available at building level	Month (bills)	ICF NOVEDIS	From January 2014 until October 2014
Comfort parameters: T°	Data available for 10 dwellings (but	15'	NOBATEK	From February 2014 to November

and RH%	many data are missing because of radio transmission issues)			2014.
Electricity consumption (general, lighting)	Data available for 10 dwellings (but many data are missing because of radio transmission issues)	10’	NOBATEK	From February 2014 to November 2014.
Recovered energy through the Biofluides system	Data available at building level	Half an hour	BIOFLUIDES	From the end of August 2014 (date of nominal functioning of the system) to November 2014
Envelope performance	Blower door, acoustic and IR thermography tests after refurbishment in one dwelling	Once after refurbishment	NOBATEK	Measured conducted in September 2014

Table 31: Data available for the periods before and after refurbishment for Paris site

3.3 Analysis of final results

3.3.1 Gas consumption

The following graph shows the changes in gas consumptions for the whole building. The data are displayed using adjustment to HDD 2011. For the baseline period, gas consumption corresponds to heating. For the period after refurbishment, the gas consumptions correspond to heating consumption of the new condensing boilers and include also the DHW production.
This data comes from bills analysis of gas consumptions (whole building) without subtracting the DHW consumptions for 2014.
It has to be highlighted that December 2013 is the first full month of gas consumption after refurbishment.
There is no gas consumption at all during the summer months for 2011, 2012 and 2013 (July, August and September) because there is no need to heat the dwellings during this warm period (the boiler was completely turned off during the summer months).
For the year 2014, a small gas consumption is still observed during the summer month. This consumption corresponds to the hot water backup heating (implemented during the refurbishment period). Moreover the heating system has been operating from 15/10/2013 to 22/05/2014 and it has been put again into service on the 09/10/2014. For the winter months, an important decrease in gas consumption is observed between the baseline period and the reporting period.

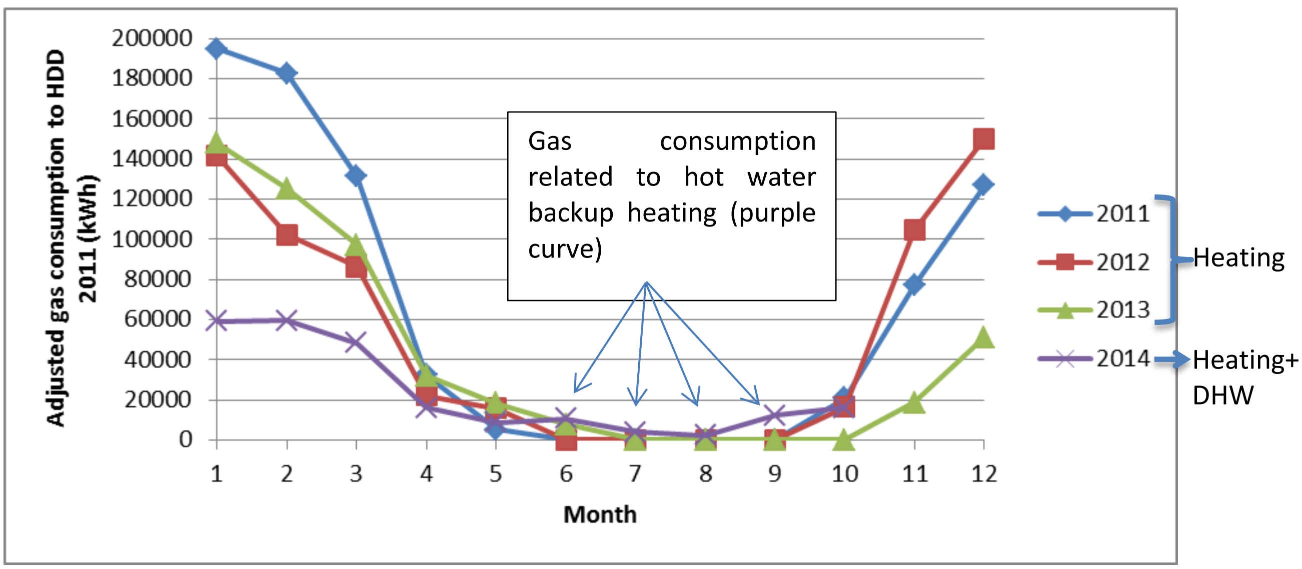


Figure 48: Monthly gas consumptions in the French site

Table 32 shows the comparison between HDD adjusted gas consumptions of the different years investigated. Generally, on a monthly basis, a decrease of consumption is observed. The savings value depends on the year which is considered for the comparison. The mean value is around 48%.
It should be noticed that for the summer months (June, July, August and September 2014), there is no saving since the gas is used for the hot water production in 2014 whereas before refurbishment, the gas was only used for the heating production which was stopped during the summer months. October 2013 should be considered as a specific month (not included in the savings calculation) since the outdoor

temperature was particularly warm so that no heating was required for this month. The same applies for May 2011.

	Changes between 2011 and 2014 (%)	Changes between 2012 and 2014 (%)	Changes between 2013 and 2014 (%)
January	-69,6	-58,1	-60,0
February	-67,5	-41,9	-52,6
March	-63,1	-43,9	-50,1
April	-50,0	-26,6	-49,4
May	--	-44,4	-51,9
June-July-August-September	--	--	--
October	-23,5	-2,6	--
Mean value	-54,7	-36,2	-52,8

Table 32: Changes in yearly gas consumption between the baseline period and the reporting period

The following graph shows the large decrease of gas consumption (sum from January to October) observed between the baseline period and the reporting period. It has to be highlighted that the decrease of heating consumptions should be higher than the figures given here, because in 2014 the backup DHW production was also counted in the gas consumption[6]. The difference between 2014 and 2011 corresponds to 58% energy savings.

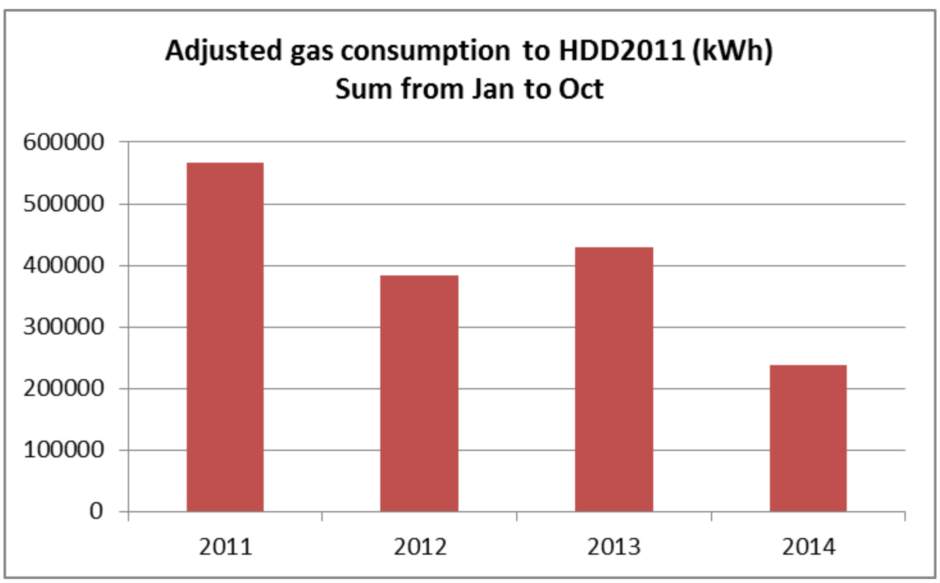


Figure 49: Comparison of adjusted yearly gas consumptions (HDD 2011 adjusted, cumulated on the ten first months of the year, from January until October) for the four last years

[6] For the baseline period: $E_{Heating}=E_{Gas}$ and $E_{DHW}=E_{Electricity\ DHW}$.
For the reporting period: $E_{Heating+DHW}=E_{Gas}$.

3.3.1.1 Heating

Because of delay in the refurbishment works, the flowmeters allowing to separate the two kinds of production of the boiler (heating and DHW) were not installed on time to have reliable results over a long period of time. Therefore an estimation of heating consumption has been made by subtracting the DHW related gas consumption to the total gas consumption of the whole site ($E_{GasHeating}=E_{Total\ Gas}-E_{GasDHW}$). This has been done for the warmer months (June, July, August and September for which we know that the heating system is shut down). Nevertheless, these months are not completely representative for the DHW consumption because they partly correspond to holiday periods when inhabitants are not present in the dwellings during several days even several weeks during this period.
The heating estimation has been made for the first months of the year (Jan, Feb, Mar, Apr, May). The following figure shows the changes and comparison of heating consumption for the different years considered.

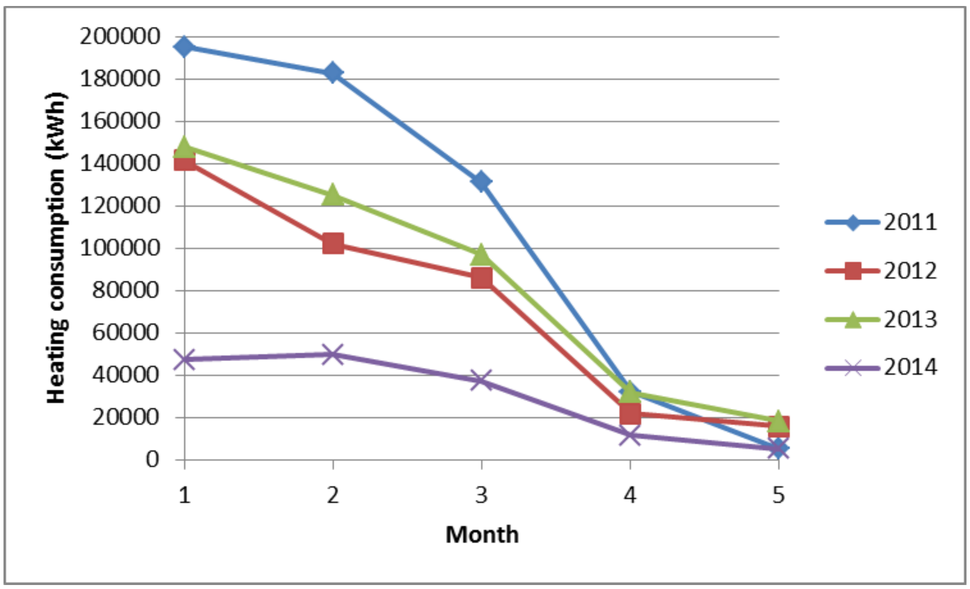


Figure 50: Heating consumption for the five first months of the year

Table 33 gives the heating consumption values obtained for the investigated years (adjusted to HDD 2011). The values for 2014 are extrapolated from the measurements collected during the first 6 months of the year (from January to June). The savings achieved between 2011 and 2014 are about 60% and fall to 35% for the comparison between 2013 and 2014.

	2011	2012	2013	2014
Adjusted heating consumption (kWh/year)	771081,0	639016,8	498206,2	321693,5
Adjusted heating consumption (kWh/m²/year)	177,2	146,8	114,5	70,9
Savings (%) compared to 2014	-58,3	-49,7	-35,4	

Table 33: Changes in heating consumption between the baseline period and the reporting period (extrapolation of 2014 heating consumptions from the 6 1st months of the year)

Another evaluation has been done considering only the available data. Data were used from January to October of each year (Table 34) without making any data extrapolation to a whole year. The results are better here considering the real data only (without using extrapolation) and provide a mean energy savings value of about 65%.

Sum from Jan to Oct	2011	2012	2013	2014
Adjusted heating consumption (sum of data from Jan to Oct) (kWh)	567458,0	384461,3	428454,7	165484,6
Adjusted heating consumption (sum of data from Jan to Oct) kWh/m²	130,4	88,3	98,5	36,5
Savings (%) compared to 2014	-72,0	-58,7	-63,0	

Table 34: Changes in heating consumption between the baseline period and the reporting period (cumulated data from Jan to Oct of each year considered)

3.3.1.2 Domestic hot water

Three data sources have been investigated regarding the domestic hot water use:
-First, the data related to the gas consumptions selected for the summer months during which the heating is stopped. During this period, the gas consumption is directly related to DHW production (from the beginning of June 2014 until the end of September 2014 included). In order to get the whole energy used for the DHW production, the electricity consumption of the BIOFLUIDES system should be added to the gas energy.
-Second, some meters located directly at systems level (one flowmeter measuring the overall water passing through the BIOFLUIDES and next through the gas boiler to provide hot water to the building and one energy meter measuring the amount of energy produced by the boiler for the DHW only, see the outline schematic of DHW production in annex 4) have also been collected. The data from these meters were available only for a short period of time (from the beginning of November 2014). The energy produced by the BIOFLUIDES system has been collected too. It also contributes to the overall energy balance of the DHW production (free source of energy).
-Third, the data coming from the SYNCO LIVING system (DHW meters installed inside the dwellings) have been collected for a longer period, between the 30/04/2014 and the 13/11/2014.

All the data have been adjusted to yearly information divided by the surface (kWh/m².year).
The results coming from the two first sources should be similar, when the third one should be lower, highlighting the heat losses appearing in the DHW circuit. The thermal energy data allow the detailed analysis of the real functioning of the systems and the identification of losses appearing in the installation whereas the analysis of consumed energy (gas +electricity) provides energy figures on which the savings calculations are based.

Table 35 gives the different parameters related to the DHW use and production assessed using the three sources of information mentioned above.
These figures highlight a large amount of heat losses between the DHW production (exit of the gas boilers) and the DHW consumption at dwellings level. The amount of energy used to maintain the

overall DHW circuit at the same temperature is about 24 kWh/m²·year that represents 55% of the whole energy produced by the boilers.
It should be noticed that the calculations introduce some parameters (based on hypothesis) that could add small uncertainties in the evaluation. For instance the DHW meters are measuring liters and a conversion is performed in kWh taking into account the cold and hot water temperatures (15°C and 60°C). It should be also highlighted that some discrepancies can occur and can be due to the boiler efficiency which is not taken into account in the calculation.

Kind of information	Source of measurement	Amount of energy (kWh/m².year)
Energy consumption	Gas bills (summer months) + BIOFLUIDES electricity consumption	33.3 (29.9 for gas + 3.5 for electricity consumed by the BIOFLUIDES system)
Thermal balance	Meters located at the system level (energy meter measuring the amount of energy produced by the boiler for the DHW production and the DHW loop)	29.9[7]
Thermal balance	Energy meter measuring the energy produced by the BIOFLUIDES system	14.2
Thermal balance	Amount of energy produced by the boiler and the BIOFLUIDES system together	44=14.2+29.9
Thermal balance	DHW meters (located in the dwellings)	19.9

Table 35: Parameters related to DHW use and production measured after refurbishment

BIOFLUIDES SYSTEM

Within the following paragraph, a specific focus is made on the BIOFLUIDES system and the results obtained for this specific innovative system.
For reminder, the principle of the BIOFLUIDES ENVIRONNEMENT E.R.S.® (Energy Recycling System) consists in recycling the heat lost in wasted water, coming mainly from showers, baths, washing machines and dishwashers. In the Paris site this water is used to preheat the hot water via a heat exchanger. An outline schematic of the DHW production system is provided in annex 4.
In the Paris site, the BIOFLUIDES system has been put into service the 21/05/2014. Several operational system failures have imposed to stop the system several weeks after that. Finally, it has been put into service again on the 10/07/2014 and can be considered as optimally functioning from the 22/08/2014. The system performance analysis has been conducted from that date.
The following graph shows the energy amount which has been daily produced and consumed by the BIOFLUIDES system during the few months of functioning before the end of the BEEM-UP project. The electricity consumption is very linear and stable over time. The energy production is a little bit more fluctuating but remains in an energy range between 140 and 210 kWh per day during the summer months and shows a slight increase at the beginning of October (average value is 178kWh over the whole period). The changes over time (during the days 10/09/2014 and 03/11/2014) of these parameters are given in Figure 52 and Figure 53 and show the different periods of production (absence

[7] The energy produced by the boiler should be lowered by an order of 2-3% compared to the gas energy data because of the boiler efficiency.

of production during the night for instance). The behaviours are very similar for a day selected in September (when the outdoor temperatures are still high) and a day selected in November (when the outdoor temperatures start to decrease).

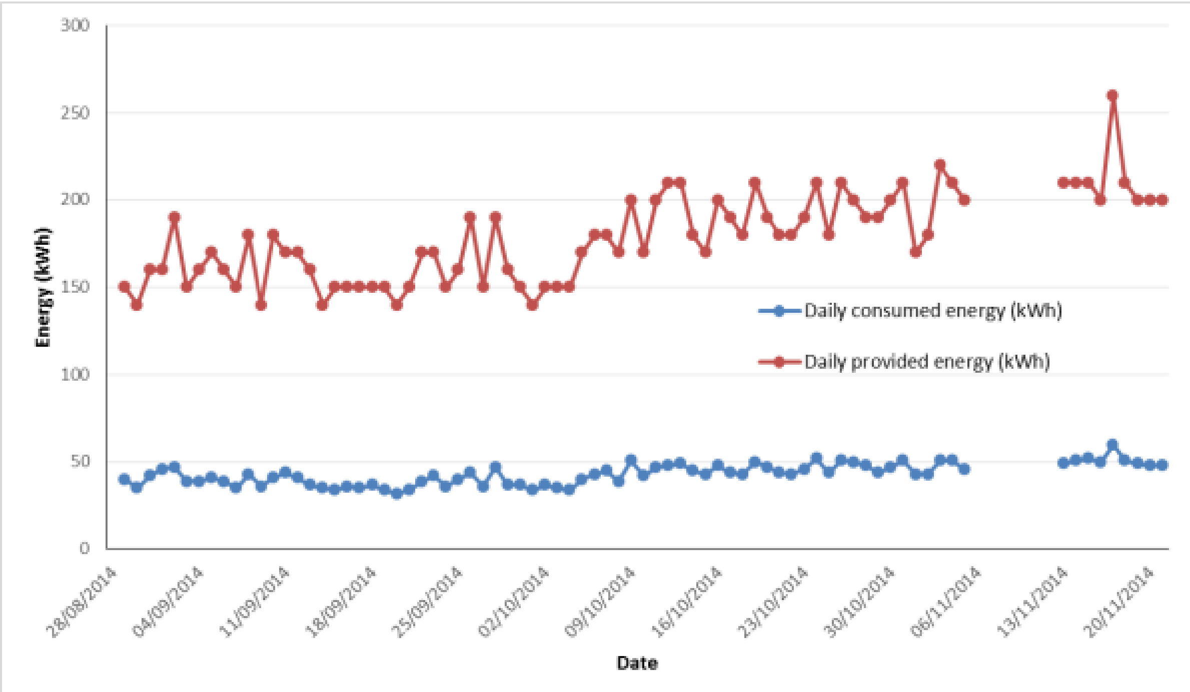


Figure 51: Energy which is daily produced and consumed by the BIOFLUIDES system

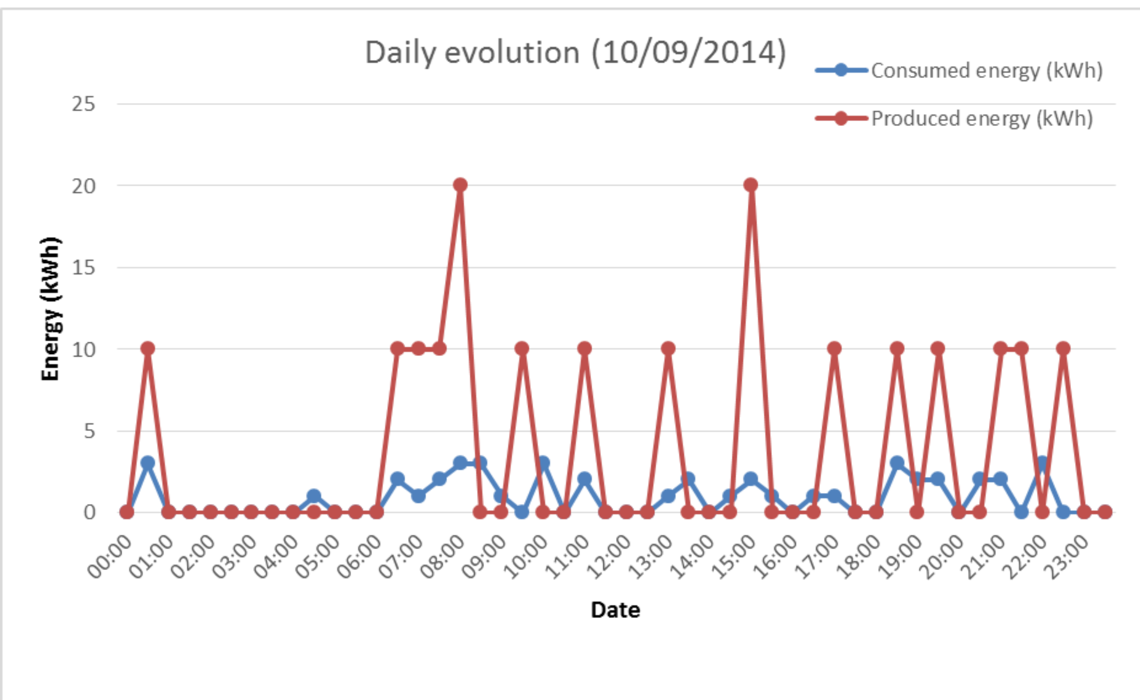


Figure 52: Changes in energy produced and consumed by the BIOFLUIDES system over time (10/09/2014)

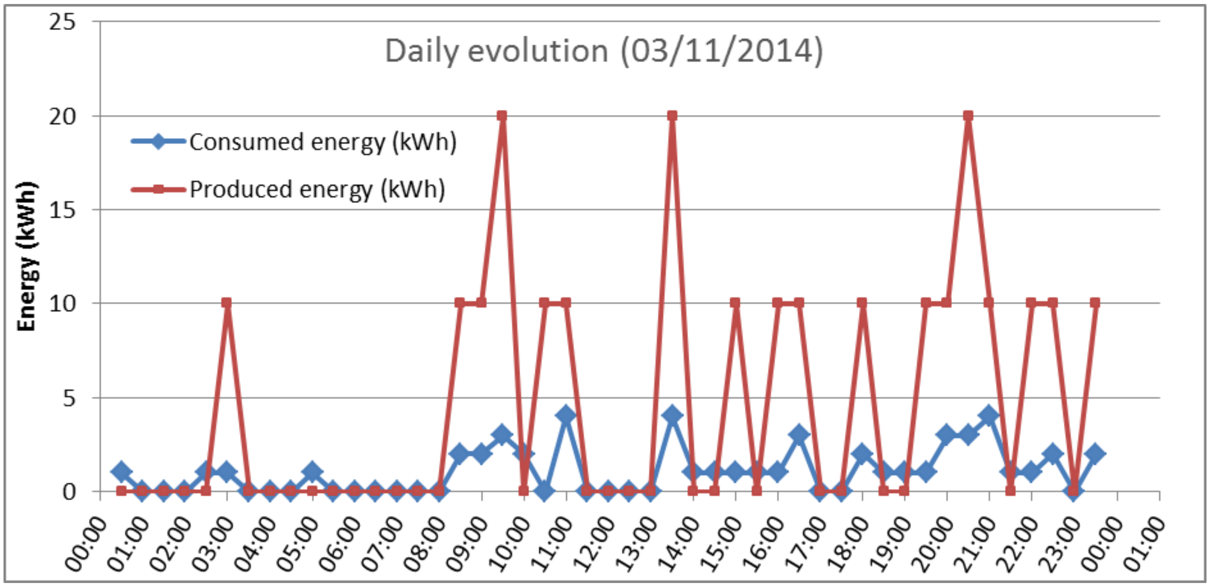


Figure 53: Changes in energy produced and consumed by the BIOFLUIDES system over time (03/11/2014)

Regarding the large amount of energy losses identified in the previous analysis, a specific investigation has consisted in analysing the DHW use during the nights. The following graph indicates that no DHW use is observed during the nights indicating that no leakage is present in the installation. This observation confirms the fact that most of the energy use is related to the DHW distribution circuit.

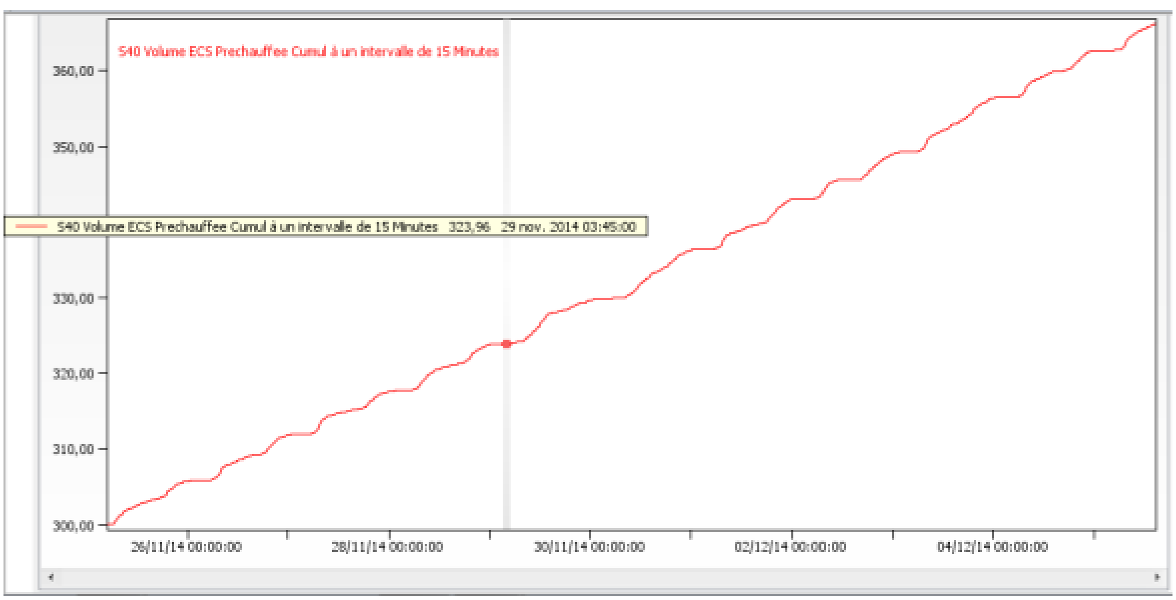


Figure 54: Changes in energy produced and consumed by the BIOFLUIDES system over time (03/11/2014)

An estimation of the savings achieved thanks to the BIOFLUIDES system has been conducted based on the first data collected during the first months of functioning of the system. Over a period excluding the issues encountered during the finalisation of the works conducted in the boiler room, the savings achieved thanks to the BIOFLUIDES system are the following:

Estimation period	Energy produced (kWh/m².year)	Energy consumed (kWh/m².year)	Savings (kWh/year)	Savings (kWh/m².year)
From 22/08/2014 to 21/11/2014	14.2	3.5	48709	10.7

Table 36: Energy produced and consumed by the BIOFLUIDES system and corresponding energy savings

This estimation is thus performed with data mainly collected during warm period (the outdoor temperature was particularly warm in October 2014). During warm period, the system is less efficient than in colder one. Therefore a higher savings value can be envisioned after a full year of system operation.
These savings correspond to the gas or electricity that has not been consumed for the hot water production.

To get the total energy use for the DHW production after refurbishment, the electricity consumed by the BIOFLUIDES system needs to be added to the gas used for the backup production ($E_{DHW}=E_{GAS\ DHW}+E_{ElecBIOFLUIDES}$). A first estimation has been made according to the data collected from the moment when the system has been put into service on the 22/08/2014 until the 21/11/2014.
The Table 37 give the main figures obtained.

There is almost no saving observed for the DHW consumptions in the Paris site even if the BIOFLUIDES system is providing free energy for the hot water production. This is due to the large amount of energy losses observed in the DHW distribution circuit and quantified thanks to the monitoring process.
This result is not in agreement with the project objectives and is also far from the results obtained with the simulations.

A complementary analysis has been conducted in order to understand the reasons for such a discrepancy. The electricity consumptions evaluated for the BIOFLUIDES system functioning are well correlated between the measurements and the predictions. But the gas consumptions are largely underestimated by the simulations. It should be highlighted that the BIOFLUIDES system with the heat pump rises temperature up to 47°c, before the gas boilers finish the heating process until a water temperature located between 55°C and 60°C. Such a temperature level is required according to sanitary needs of legionella risk elimination. In addition, the gas boilers maintain the temperature in the whole hot water loop and compensating the heat losses appearing in the whole distribution network. Therefore the results obtained are highlighting the large amount of heat losses present in the distribution network of the building (around 24 kWh/m²·year). This has also been reported for other buildings built several decades ago. For these buildings, the backup system that is also in charge of the DHW circuit represents 2/3 of the overall energy needs related to DHW. For the Paris site, we are exactly in this configuration (gas consumption represents 65% of the whole energy used for the DHW production).

If we consider an optimized distribution circuit, with reduced heat losses (around 30% instead of 55%), the energy measured for the reporting period would have been about **14 kWh/m².year** that corresponds to **52% savings** in energy.

Paris	Measurements		Predictions	
	Baseline period	Reporting period	Predicted performance before refurbishment	Predicted performance after refurbishment
	kWh/m^2.year	kWh/m^2.year	kWh/m^2.year	kWh/m^2.year
Domestic hot water (real conditions)	29.1 (monitoring data) 28.5 (audit)	33.3 (with 3.5 kWh/m^2/year for electricity used by the BIOFLUIDES system)	16.7	9.8 (3.4 for electricity and 6.4 for gas)

Table 37: DHW consumption - Comparison between baseline and reporting periods, and comparison between measurements and predictions

It should be emphasized that the measured values are well above the predictions including for the baseline period. The predictions largely underestimate the DHW consumption and this is mainly due to the hypothesis taken for the calculations. Indeed, Table 38 gives the mean values of DHW consumption in the residential sector in France according to the size of the dwelling (40l/day) whereas the calculations hypothesis (shown in Figure 55) consider 25l/person/day which seems very low for the Paris site. This can explain the large discrepancy observed between the measured DHW consumptions and the predictions for the baseline period as well as for the reporting period.

Number of rooms of the dwelling	1	2	3	4	5
DHW consumption (l/day) 60°C	40	55	75	95	125

Source http://www.tecsol.fr/Lettres/articles/Documents/ECSsolaire1.pdf

Table 38: Mean values of DHW use in France according to the size of the dwelling

PROJECT DATA			
	ICF - Rue du Cotentin 97		
	Paris		
	Rue du Cotentin 97		
	Paris		
Country:	France		
Regional climate:	F- Paris		
Building			
Treated floor area	4.352 m²		
Number of dwelling units	87 units		
Energy related data			
PE-and CO2-Factors	PE-Factors	CO2 emission factors	Comment
Oil	1,1	0,3	
Natural Gas	1,1	0,3	
LPG	1,1	0,3	
Hard Coal	1,1	0,4	
Wood	0,2	0,1	
Electricity-Mix	2,7	0,7	
Electricity from Photovoltaics	0,7	0,3	
Hard Coal CGS 70% PHC	0,8	0,2	District heat
Hard Coal CGS 35% PHC	1,1	0,3	District heat
Hard Coal HS0% PHC	1,5	0,4	District heat
Gas CGS 70% PHC	0,7	-0,1	District heat
Gas CGS 35% PHC	1,1	0,1	District heat
Gas HS0% PHC	1,5	0,3	District heat
Oil CGS 70% PHC	0,8	0,1	District heat
Oil CGS 35% PHC	1,1	0,3	District heat
Oil HS0% PHC	1,5	0,4	District heat
Internal heat gains			
Internal heat gains QI	2,10 W/m²		
DHW + Distribution			
DHW Consumption per Person and Day (60 °C)	25,0 liter/person/day		
Average Cold Water Temperature of the Supply	10 °C		

Figure 55: Main hypothesis used for the calculations for the Paris site

Note: a recent problem has been detected on the BIOFLUIDES system (from the 22/11/2014). The production of BIOFLUIDES has been stopped. This was due to the fact that the mesh filter located in the catchment circuit was full of wood chips. This phenomenon is normal during the first months of operation of such an installation. The cleaning of the filter is a common operation included in the normal maintenance of this kind of installation and the operator of the building should have performed this operation within the frame of his maintenance contract. This point highlights the fact that a commissioning approach is always beneficial when a new system is installed.

3.3.2 Electricity

3.3.2.1 Common electricity consumption

The following data comes from bills analysis of electricity consumptions for the common areas of the building. A general increase in common electricity consumption is observed at the beginning of the year when the refurbishment works are not finished. This increase can be explained by the refurbishment works (use of lifts by the workers, lighting of the basement during the works, more people present in the common areas,…). When evaluating the same data for the next months, a decrease in common electricity consumption is observed between the baseline and the reporting periods.

	2012	2013	2014
Electricity consumptions of common spaces (kWh)	21054	33714	10285

Table 39: Yearly electricity use for the common areas of the building (value calculated with data available until August 2014)

%	Difference between 2012 and 2014	Difference between 2013 and 2014
Jan to Aug	-36	-53.8
Jan to Feb	+23	+13.1

Table 40: Changes in electricity use for the common areas of the building

3.3.2.2 Individual electricity consumption

The individual electricity consumptions have also been measured for the Paris site.
This measurement is achieved by using some clamps plugged onto the different lines to be measured:
-First the general line that feeds the whole dwelling is measured;
-Second the distribution line related to lighting is measured separately.
The measurements are collected for a sample of dwellings and then extrapolated to get the yearly consumption of all the dwellings. This constitutes a first approximation (it is assumed that the selected dwellings are representative of the other dwellings but this specific point can't be validated within the project). Moreover, some problems with disconnection in the system or damage to the sensors were noticed during the monitoring process. Besides, the remote control of the system was not possible to use because of internet access not being available before the end of the refurbishment works. These difficulties resulted in large periods where data are missing and therefore weaken the results.
The following table provide the results of the measurements performed:

	Before refurbishment		After refurbishment	
	Total Electricity Consumption*	Electricity Consumption for lighting*	Total Electricity Consumption*	Electricity Consumption for lighting*
Value (kWh/m².year)	100	2.3	41.7	4.6
Savings (%)			-58.3	+100

* Estimated from the measurements performed in a sample of dwellings

Table 41: Changes in electricity consumption at dwelling level

The general electricity consumption has decreased after refurbishment (58.3%) but the presented results are based on an estimation made with the data collected for a sample of dwellings. The same applies for the lighting results. Therefore the results should be considered with caution.
Moreover, it should be highlighted that the lighting measurement is not completely reliable because when people use lamps directly plugged on the general electricity distribution of the dwelling, the lighting measurement does not take into account this as a lighting consumption. It is considered in the general electricity consumption. Therefore the lighting consumption may be underestimated compared to the reality and the simulations and should also be considered with caution.

3.3.3 Comfort conditions analysis

The graph below shows the thermal behavior of the dwelling n°212 during the reporting period. The meteorological data come from the online free database www.wunderground.com. A tendency curve of the outdoor temperature has been drawn to make the data reading easier. The indoors temperature in the living and the sleeping room are presented.

We can firstly observe that the temperature difference between each room is stable and never excess 2°C. It shows a good regulation into the apartment area.

The indoor temperature remains in a comfort range (19°C < Tint > 28 °C) almost all the time. There are only 40 hours during all the reporting period showing a temperature in the living room out of the comfort zone (the temperature doesn't decrease under 18.5°C). This period appears in May (28/05) when the heating system is not active.

We can observe that the average temperature is increasing during the summer period (June-August). But it doesn't impact the comfort conditions. It's considered that the higher temperature supported is increasing with the outside temperature, with a limitation of 28°C for less than 48 continuous hours (reference: http://www.enertech.fr/modules/catalogue/pdf/44/T18_confort%20ete.pdf).

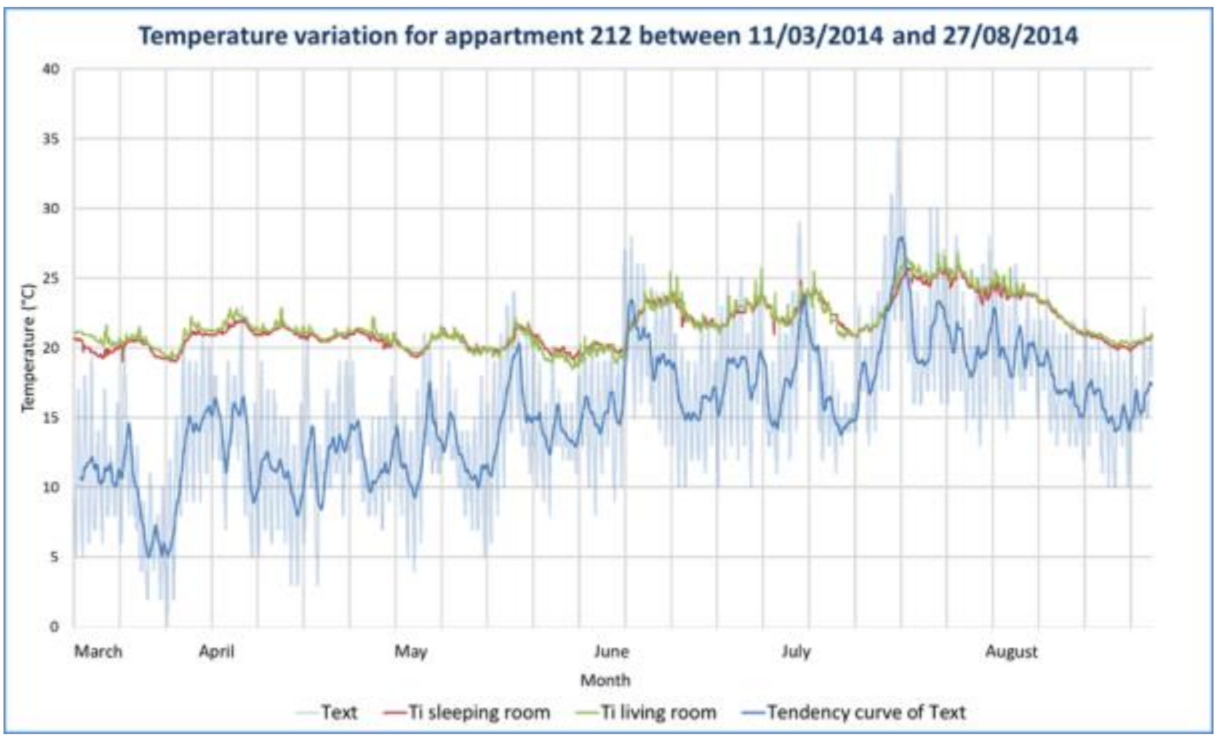


Figure 56: Changes in the indoor temperature for dwelling #212

The following graph shows the indoor temperature changes for the two warmest weeks of the reporting period. The highest outdoor temperature of the year is reached during the week from 14/08 to 20/08. The highest indoor temperature isn't reached during the warmest day of this week. Due to the building inertia, the temperature peak is spread over the time. It also shows that tenants had a good behavior and let the windows closed during the warmest hours.

The second week presented shows the annual highest temperature for the apartment, reached in the living room (26,8°C on the 27/07 at 7pm). We can see that this happens after a long and regular warm period (9 days on 12 reach or exceed 25°C during the afternoon).

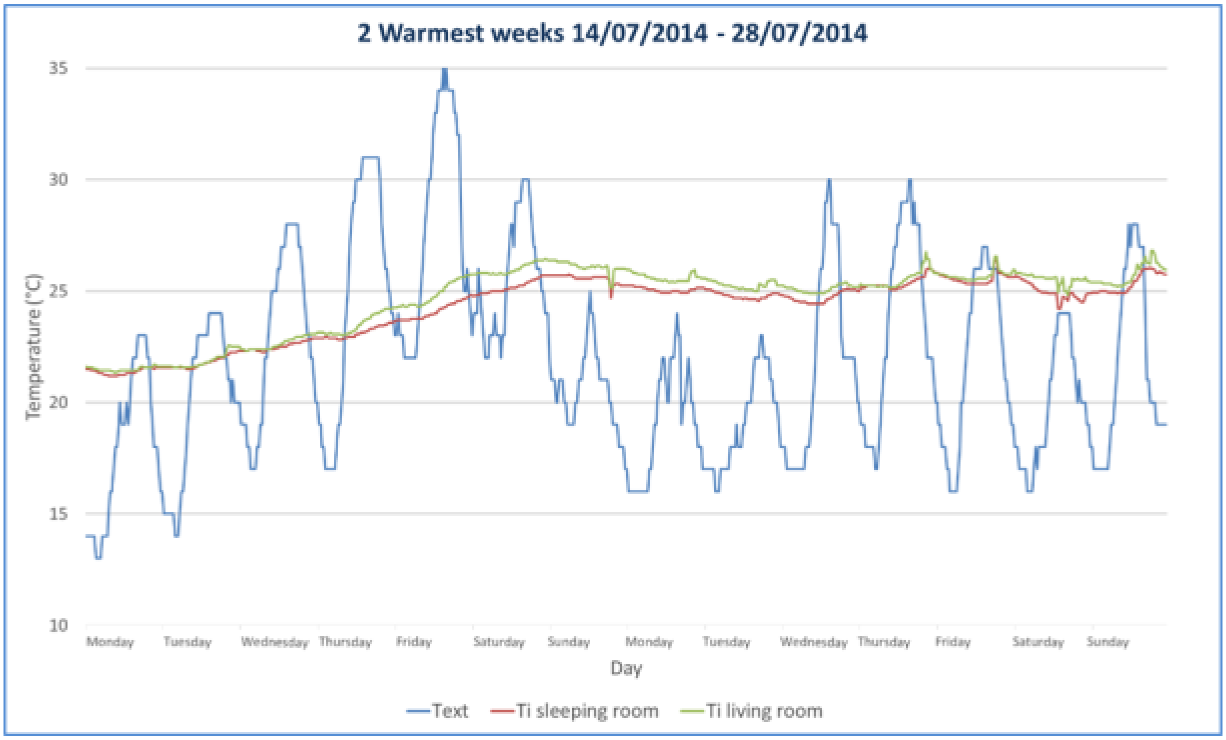


Figure 57: Changes in the indoor temperature for dwelling #212 during the warmest weeks of the year 2014

The following graph presents a good example of building inertia effect. The changes in indoor temperature are softened compared to the outdoor one.

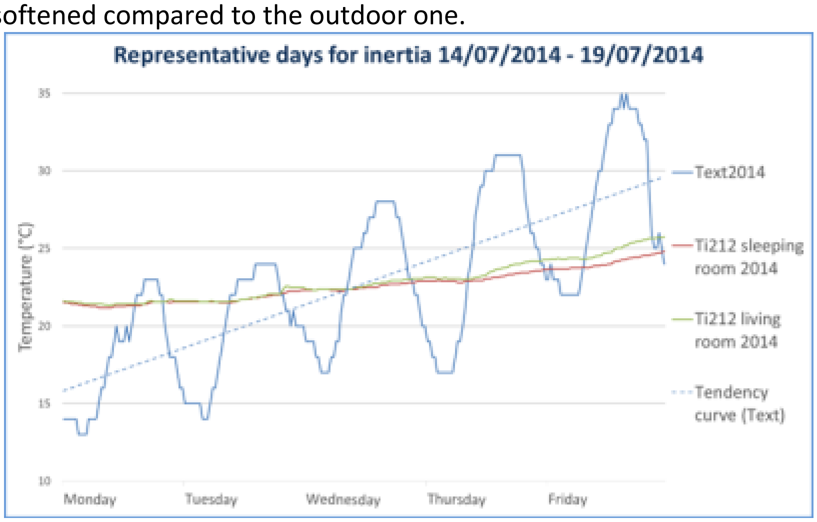


Figure 58: Changes in the indoor temperature for dwelling #212 representative of building inertia

During the baseline period it has not been possible to install sensors in dwelling 212. To compare the available data of apartment 212 to representative data of the baseline period, data were collected in an apartment having the same characteristics (apartment 262). It presents all the similarities needed to make an efficient comparison. Its location on the 6th floor is the same as the #212 in the 2nd floor. It's also a middle apartment, meaning that it is located between two apartments up and down, so heating losses by walls can be considered equivalent.

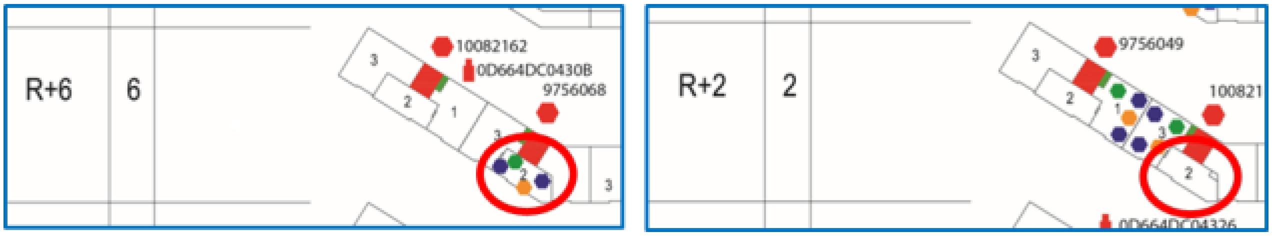


Figure 59: Location of the dwellings selected for comparison of comfort conditions

The two following graphs present 5 representative days for the building inertia and the efficiency of regulation. For days with similar outdoor temperature tendency the fluctuations of indoor temperature are more important during the baseline period. The same trend is observed in Figure 61. These graphs show the temperature difference between the baseline and the reporting period between the 04/04 and the 23/05 for the respective years of 2012 and 2014.

The temperature gradient is more important during the baseline period. It reaches 4.9°C (24/04/2012) difference between both rooms. The temperatures considered were taken out of the peak time described below to exclude the impact of tenant's behavior. In the same time the temperature difference between two rooms during the reporting period never exceeds 1.3°C (27/04/2014).
The reporting period appears well regulated; the temperature still remains within a 3.6°C range. In the same time the baseline data shows a large variation within a 8.4°C range. Even if the outdoor temperature presents some important variation during the baseline period (from 0°C to 28°C for 2012 and from 2.5°C to 24.5°C for 2014), the temperature gradient is still 32% superior compared to what the reporting period data shows.

Without refurbishment when the temperature is under approximately 6°C, the indoor temperature decreased spontaneously. Those peaks appear essentially in the morning or around midday. They can surely be explained by windows opening to ventilate the apartment when the tenants woke up or came back for lunchtime at home.

Those items reveal that the refurbishment operation has improved the thermal behaviour of the building. A better homogeneity on the temperature repartition is obtained around apartments. The stability of the indoor temperature has a significant impact on the inhabitants comfort.

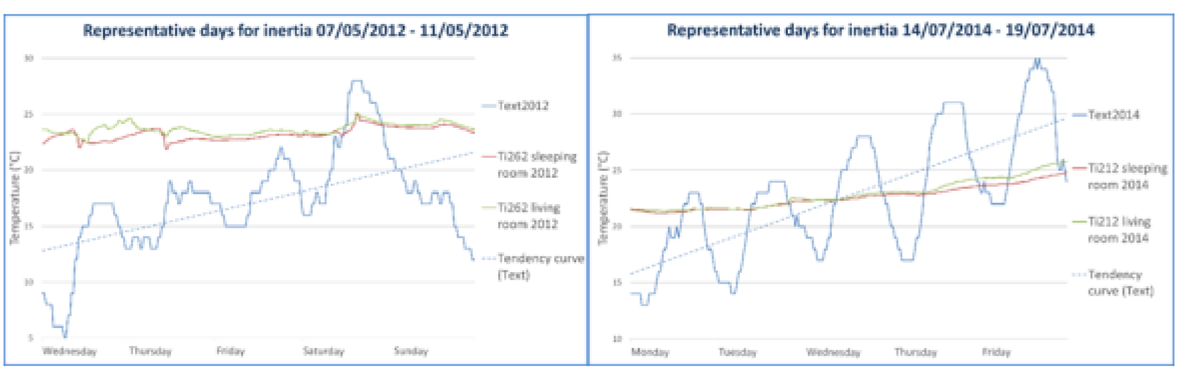


Figure 60: Changes in temperature showing the inertia effect observed in the building

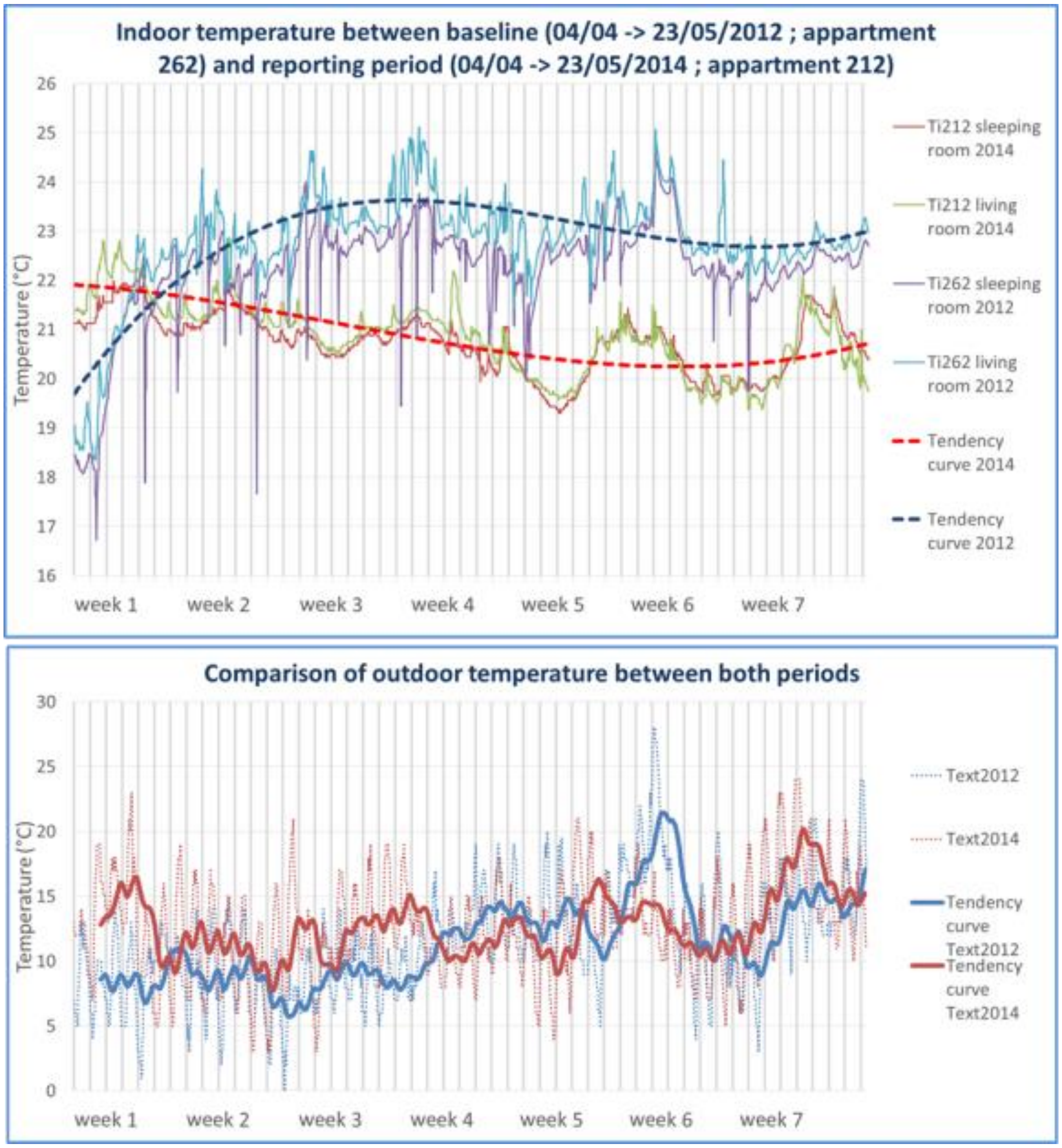


Figure 61: Comparison of temperatures measured in similar dwellings for the baseline and reporting periods

The following table gives some representative figures of the improvements related to comfort conditions after refurbishment.

Comparative results between baseline and reporting period	Baseline period	Reporting period
Tmax (°C)	25.1	26.8
Tmin (°C)	16.7	18.5
Hours out of comfort (<19°C or >28°C)	71	40
Mean temperature (°C)	22.5	21.6
Highest temperature difference between rooms (°C)	4.9	1.3

Table 42: Comparison of indoor temperatures between baseline period and reporting period

Another comparison had been made for the autumn period with two other apartments. These apartments have been chosen to be compared because of their similar charactieristics (cf. appartment repartition).

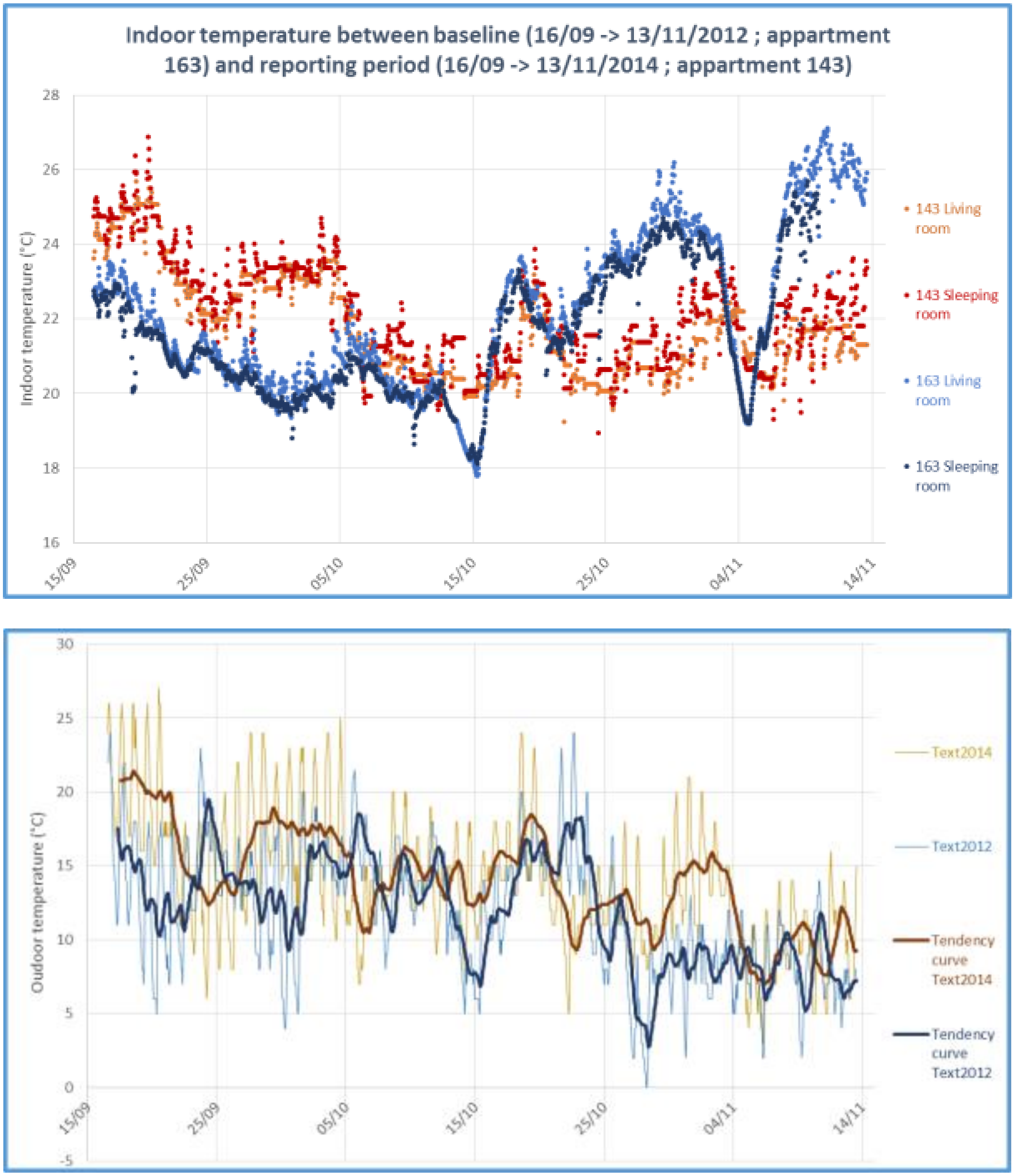
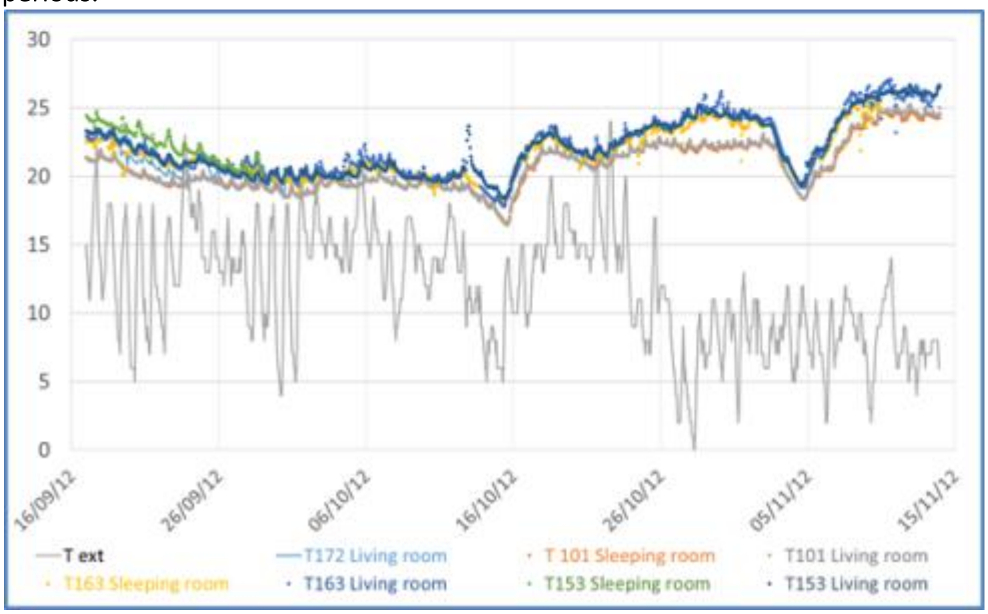


Figure 62 : Comparison of temperatures measured in similar dwellings for the baseline and reporting periods

The graph above shows that the thermal behavior of these appartments during the automn period show differences. Globaly the temperature in 2014 is greater than the one measured in 2012. This observation is in good agreement with the high temperatures observed during September and October 2014 in France. During the first part of the period (from mid-September to mid-October) the temperatures are higher in the appartment n°143 (reporting period). This can be explained by a higher outdoor temperature during those days in 2014 compared to 2012 but the indoor temperatures still remain in the comfort zone. In the second part of the period (from mid-October to Mid-November, the heating system was started on 9th of October 2014), the situation is reversed. The appartment n°163 (baseline period) shows a temperature setpoint pretty hight (an average of 25 °C) whereas the appartement analysed for the reporting period shows much more reasonable temperature.

The two following graphs represent the thermal behaviour of several apartments during a similar period in 2012 and 2014. These apartments have been selected according to the data availability during the respective periods.



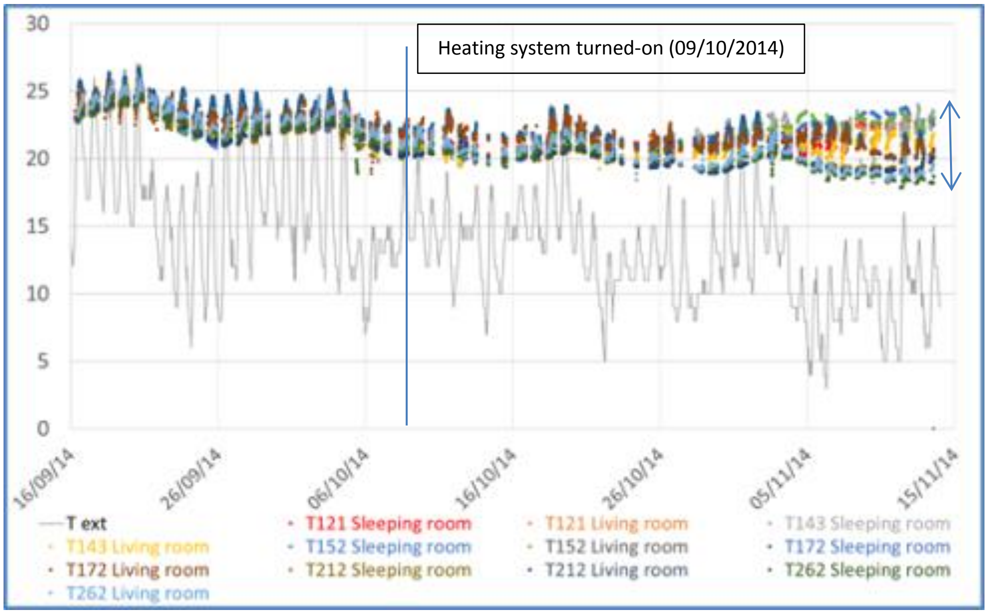


Figure 63 : Indoor temperature changes in several appartments during a similar season of 2012 (up) and 2014 (down)

In 2014, the heating system was turned-on on the 9th of October. From this date an average temperature between 21 and 23°C is observed for all the dwellings investigated. During the same period in 2012, the temperature presents a higher average value located for half of the time between 23 and 25°C (1 or 2°C above the indoor temperature measured after refurbishment that could explain a higher energy use for the heating production also). Before renovation, the radiant floors didn't allow a good management of the heating whereas after refurbishment, the radiators with individual thermostat provide an easier and more reliable way of regulating the heating inside the dwellings.
Nevertheless, the standard deviation between the measurements collected in 2014 is increasing along the measurement period showing the influence of the user behaviour and the different types of behaviour regarding the comfort temperature.

3.3.4 Punctual measurements

3.3.4.1 Results of acoustic tests

Before refurbishment the acoustic measurements indicate a low acoustic insulation between the two dwellings (DnT,A = 44 dB, the objective to reach according to the French rules is DnT,A ≥ 53 dB).
After refurbishment, the acoustic tests were conducted in dwellings located on the first floor (Cotentin street) according to the French standard NF EN ISO 140.4. Calculations are realized according to the French standard NF EN ISO 717-1. The detailed results related to the acoustic tests performed after refurbishment are provided in annex 5.

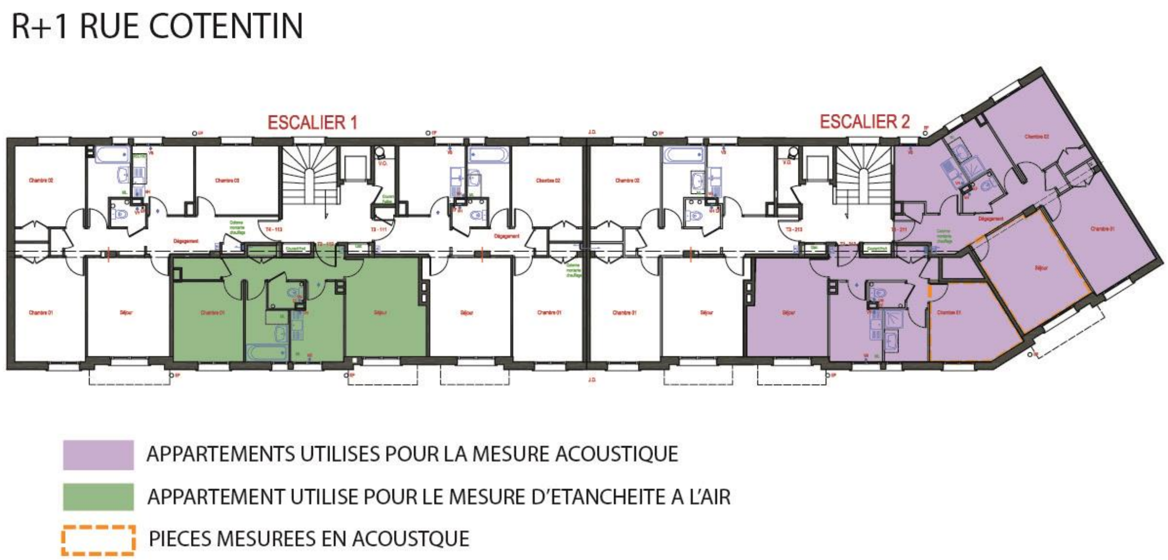


Figure 64: Location of dwellings in which the acoustic tests after refurbishment were performed (purple zone)

The aim of the measurements was to evaluate the efficiency of the double wall installed between the two rooms as shown on the following figure. The measurements were conducted by installing a noise source in the living-room of the first dwelling and then measuring the noise level in the bedroom of the second dwelling. The main sources of noise are highlighted with the red circle shown on Figure 65.

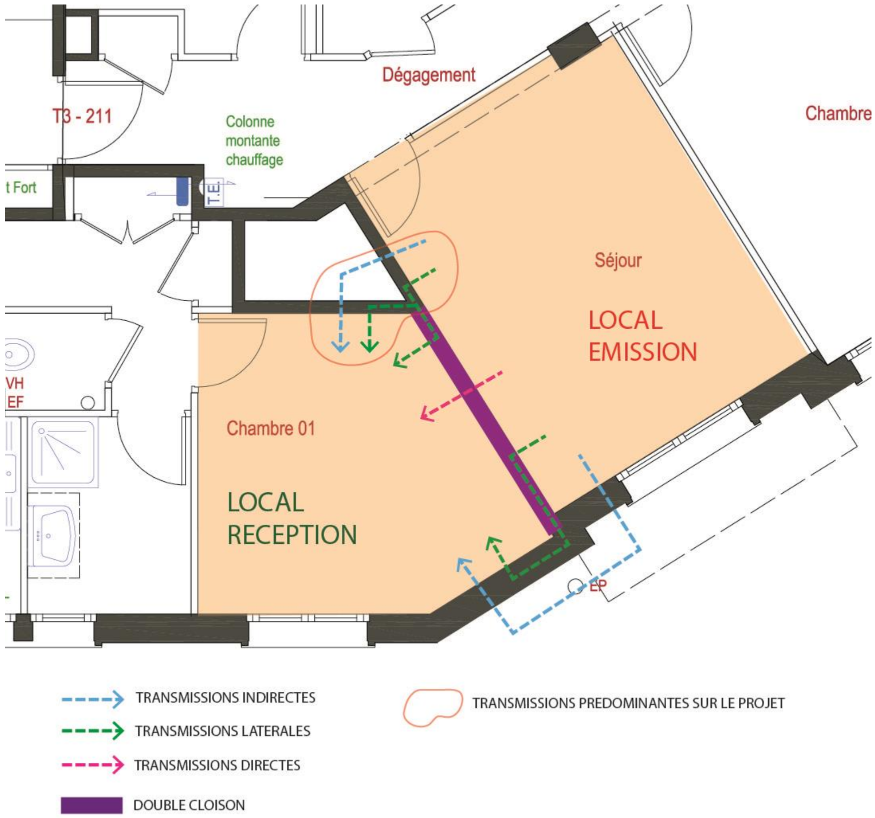


Figure 65: Principle of acoustic transmission between the two rooms tested

The results obtained indicate an insulation level of DnT,A = 46dB which is just above the value obtained before refurbishment. In the studied configuration, the main acoustic insulating defaults come from indirect and lateral acoustic transmissions as shown on Figure 65. These defaults lead to a poorer global acoustic insulation even if the double wall has a real impact on the acoustic transmission between the two rooms.

In a quantitative way, the measured value does not reflect the improved perceived by the tenants who were interviewed about their feeling regarding the acoustic improvement of the apartments. The tenants have really observed an improvement in the bedrooms where a double wall has been installed.

But as the dwellings were partly improved regarding the acoustic insulation (wall cover only in the back of the room), the measurements do not reflect these improvements. Using this configuration, the noise is still transmitted through the walls that were not modified and therefore the improvement is not as significant as if all the walls have been modified.

3.3.4.2 Results of air leakage tests

Before refurbishment, the main weak points observed within the dwellings were located on the joineries as shown on Figure 66.

Figure 66: Damaged seals leading to leakages highlighted with the smoke generator (before refurbishment)

The same phenomenon is clearly emphasized thanks to the IR thermography images taken as shown on Figure 67. Air leakages are highlighted in blue colour and they are due to damaged joineries.

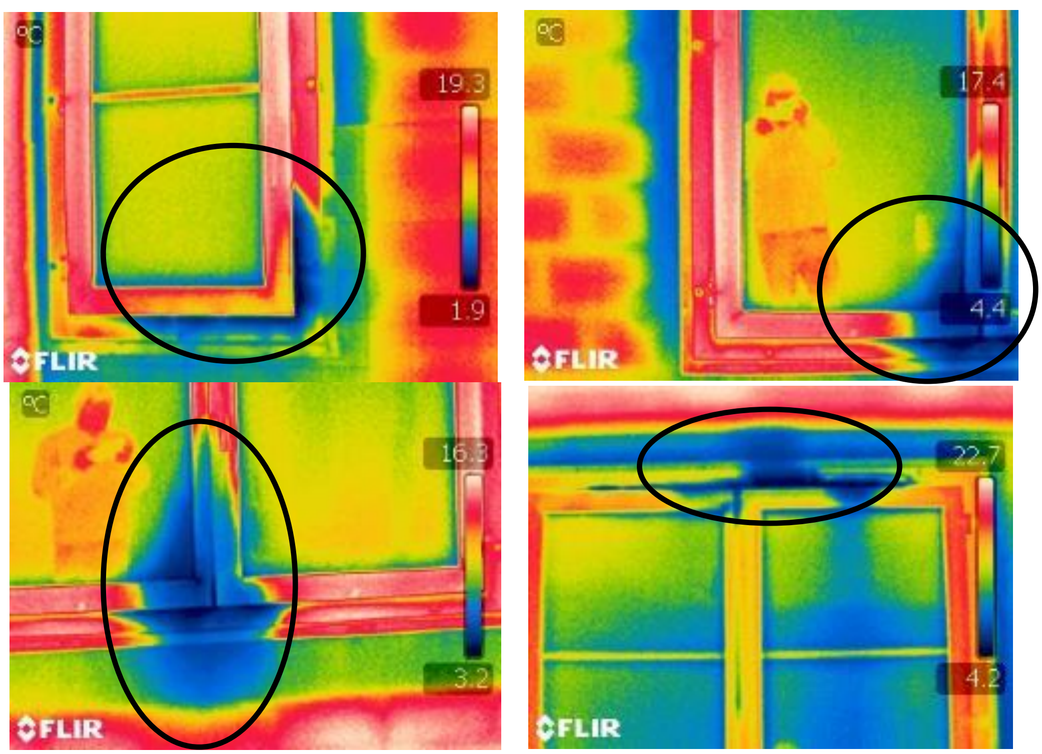


Figure 67: IR photos taken during the depressurization of the dwelling (before refurbishment)

Despite these observations, the results of the measurements were quite satisfactory with a Q4 value of 0.45 $m^3/h.m^2$ (the value for low energy consumption building being Q4 = 1 $m^3/h.m^2$).
Other IR thermography photos have been taken and show that apart from the leakage detected on the joineries, some thermal bridges exist as illustrated in the following figure.

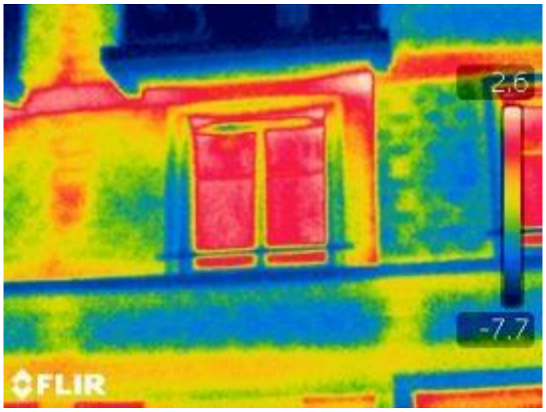


Figure 68: Thermal bridges

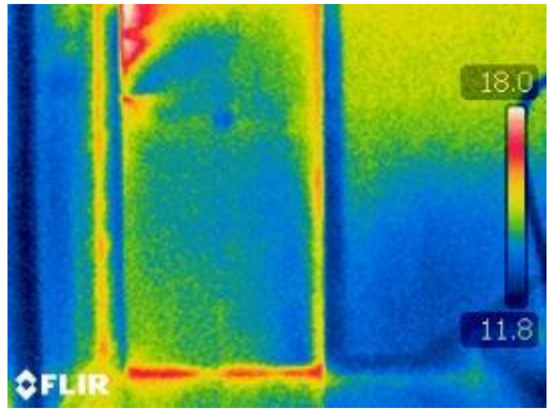


Figure 69: Air leakage located at the entrance door

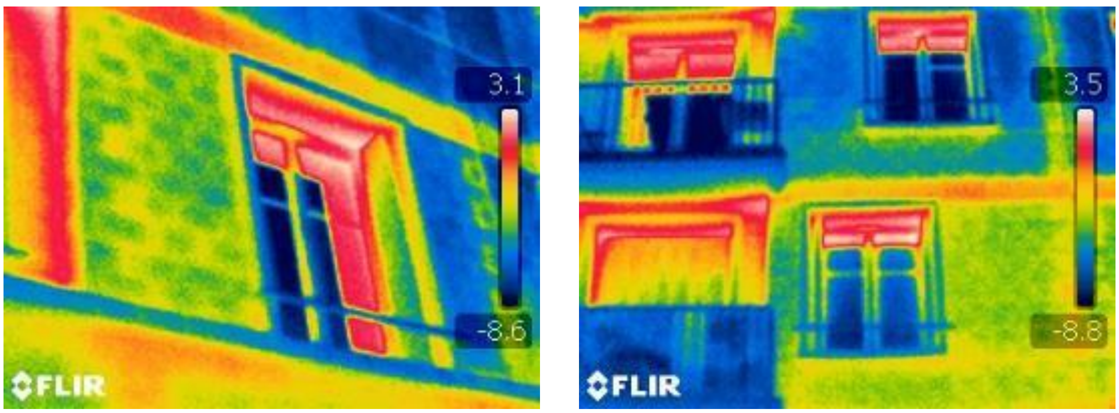


Figure 70: Thermal leakage located at the joineries (before refurbishment)

After refurbishment, the measurements were conducted in the same dwelling (#112) as for the measurements performed before refurbishment according to the French standard NF EN 13829.
The results obtained show an improvement of the air tightness of the dwelling. The Q4 value obtained (Q4=0.32 $m^3/h.m^2$) is better that the one collected before refurbishment. The improvement is therefore significant and can also be observed through the IR images collected (see Figure 71). The air leakages due to tightness defaults of joineries before refurbishment have completely disappeared.

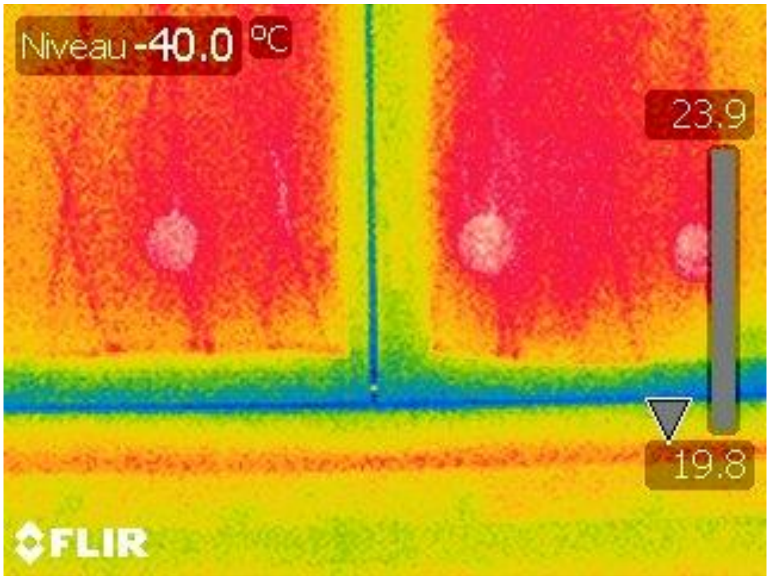


Figure 71: Thermal images taken after refurbishment

It has to be emphasized that these IR images have been taken at the beginning of September when the dwellings are not heated and when the indoor temperature is not so different from the outdoor temperature (therefore contrast can be weakened).

Therefore these punctual measurements performed in the French pilot site reveal that some improvements relative to the acoustic insulation of the dwellings and the air leakage performance are highlighted in comparison with the characteristics before renovation.

3.4 Conclusions for Paris site

The following table summarizes the main results obtained in terms of energy savings and provide a comparison with the predictions and the general objectives of the project.
In WP1 calculations were done to determine the theoretical energy performance of the building before and after refurbishment. The calculations were conducted using an operative temperature of the buildings of 20°C.

The use of general electricity and heating has decreased after refurbishment (60% savings for heating, 58% for general electricity). There is almost no saving observed for the DHW consumptions in the Paris site even if the BIOFLUIDES system is providing free energy for the hot water production.
Nevertheless, energy consumptions for heating and DHW measured during the reporting period are higher than the predicted one.

In general, some discrepancies can be observed between the calculated predictions and the real measurements.
The operative temperature used for the calculations is a little bit lower than the average indoor temperature observed in the dwellings. This can explain the discrepancy observed between the measured values for heating consumption and the predictions. Therefore the indoor temperature

constitutes a still present energy opportunity and raising awareness of the tenants can have an influence on this parameter.
Concerning the DHW, two kinds of energy are used for the production of DHW (gas plus electricity used for the BIOFLUIDES system). The gas boilers are first used to raise the temperature up to 60°C but also to maintain the DHW circuit at the same temperature and this can explain the high gas consumptions measured in 2014. The consumption related to the latter can be highly affected by the distribution circuit that in the case of the Paris site is not as performant as intended.
Moreover many other parameters related to the technical set-up of the Biofluides system may explain these discrepancies. For instance the temperature set-up for the water pre-heating could be mentioned as an influencing factor that could really affect the consumptions predictions.

Compared to the general objectives of the project, the results obtained for heating savings are lower than those expected. Nevertheless substantial savings are however achieved even if the results are preliminary (less than one year of monitoring). The results obtained for DHW are well below the objectives of the project but in this case, the configuration of the selected solution (BIOFLUIDES system for preheating + gas boilers providing additional heating and maintaining the DHW loop in temperature) may explain the poor results obtained.

	Metered			Simulated			Target
French site	Baseline period measurements	Reporting period (2014) measurements	Savings achieved (%)	Predicted performance before refurbishment (WP1)	Predicted performance after refurbishment (WP1)	Savings according to predicted performances	Objectives of the project in terms of energy savings
	kWh/m².year	kWh/m².year	%	kWh/m².year	kWh/m².year	%	%
Heating (heating degree day adjusted values)	263.8 (adjusted value to HDD used for the predictions)	105.5 (adjusted value to HDD used for the predictions)	60-65*	264.26	48.41	82	**75**
Domestic hot water	29.1 (measured) 28.5 (audit)	33.3 (real conditions) 14 (considering reduced heat losses in the DHW distribution circuit)	0/52**	16.7	9.8	41.3	**45**
Domestic electricity	100	41.7	58.3	No prediction	No prediction	62 [cf brochure]	
Electricity for lighting	2.33 (measured) 2.3 (thermal study) 3.33 (IST study)	4.6	-100	11.78	7.28	38	**42**
Indoor climate	22.5	21.6	NA		20°C		

**Depending on the period considered for the comparison (6months data and extrapolation to one full year or ten months taken into account)*

***Considering reduced heat losses (30%) in the DHW distribution circuit*

Table 43: Summary of results and comparison with predictions and general objectives of the project for the French site

Chapter 4 Conclusions

The following table summarizes the energy savings results achieved for all three sites.

	Alingsås	Delft	Paris	Objectives of the BEEM-UP project
	%	%	%	%
Heating savings	80*	45	60-65	75
Domestic hot water savings	16/8→mean value=12	-50 to + 55 Average: -14	0/52**	45
Electricity savings	36/35→mean value=35	0	58	42 (lighting)

**After optimization of the system*

***Considering reduced heat losses in the DHW distribution circuit*

Table 44: Summary of savings results for all three sites

Some pretty good results are obtained for the sites of Alingsås and Paris.
Even if some discrepancies are observed between measurements and predictions the savings achieved are in relatively good agreement with the objectives.
For Delft, the effect of solar domestic hot water systems and heaters with high efficiency is positive. But on average half of the ambitions have been reached for this pilot site.

In the case of Alingsås, the adjustments conducted on the setup of the ventilation and heating systems allowed to reach the savings values that were aimed within the BEEM-UP project and that were also predicted by simulations.

The discrepancies observed between measurements and predictions concerning heating consumptions can be partly explained by indoor temperatures used in the dwellings. These temperatures are often higher than the temperature selected for the calculations.

Regarding the electricity use, the results are mitigated. But it should be highlighted that electricity consumptions are not directly impacted by the refurbishment conducted in the pilot sites. Moreover the measurements of lighting consumptions are very dependent on the way the lighting system is used in the dwelling (lighting distribution or lamps directly plugged on the general electricity distribution of the housing). This last configuration prevents a reliable measurement of this electricity use.

While the DHW savings achieved for Alingsås do not reach the expected objectives, the BIOFLUIDES system installed in the Paris site allows going beyond the objectives. Nevertheless the large heat losses identified and quantified in the Paris site mask all the energy savings achieved thanks to the new installation (new boilers and BIOFLUIDES system).

In terms of comfort conditions, all the three sites seem to reach the expected objectives as well as those of the building owners.

As a general rule (all the following explanation is applicable for all three sites), the reasons for the differences between measurements and predictions can be the following:

- The air exchange rates before refurbishment were not measured (could be higher or lower than assumed) and this parameter can have a large influence on the calculated results in terms of heating consumptions particularly.
- The ICT savings were based only on assumptions (for the WP1 calculations, it was assumed they were of the order of 12-15%).
- The room temperatures before refurbishment could have been lower than calculated (in the case of Delft, for instance, only one room was really heated before refurbishment. But the dwellings would have been heated differently in the future as people demand higher comfort.).
- The efficiency of old building services could not be calculated exactly, only assumptions can be made (no information was available about efficiency of old components: boiler, air change rates unsure, distribution losses).
- The consumption of warm water may differ from calculations considerably (before and after) especially, as the consumptions are very much dependent on tenants´ behavior.
- The rebound effect could also be a very impacting parameter that cannot be anticipated or measured and therefore that is difficult to quantify or estimate (higher temperature after refurbishment, lower temperature than calculated before refurbishment (pre-bound effect)…).

References

[1] "D3.1: Common guideline for the monitoring program", BEEM-UP, 2013.

[2] "D3.2: Specific monitoring program for the pilot sites", BEEM-UP, 2013.

[3] BFS 2011:26 – BBR Oct.

[4] "D3.3: Monitoring equipment installed in the pilot projects in Alingsås, Delft and Paris – Updated version", BEEM-UP, 2014.

[5] http://fsd.monash.edu.au/environmental-sustainability/environmental-issues/set-points-faqs.

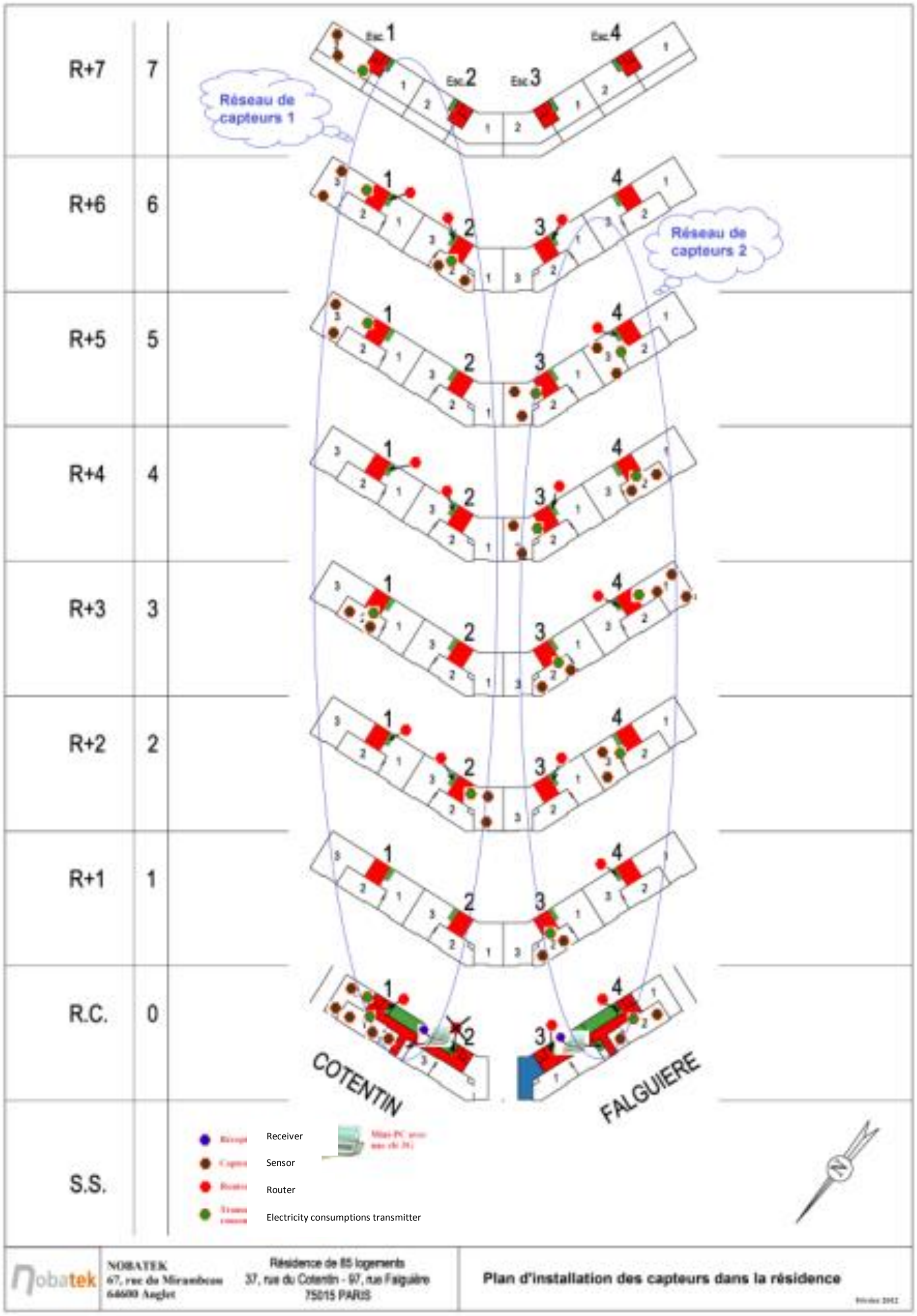
[6] http://www.cmhc-schl.gc.ca/odpub/pdf/63816.pdf.

[7] "D5.6: Post-occupancy evaluation", BEEM-UP, 2014.

Annex 1: List of dwellings equipped with monitoring devices within the baseline period in the French pilot site

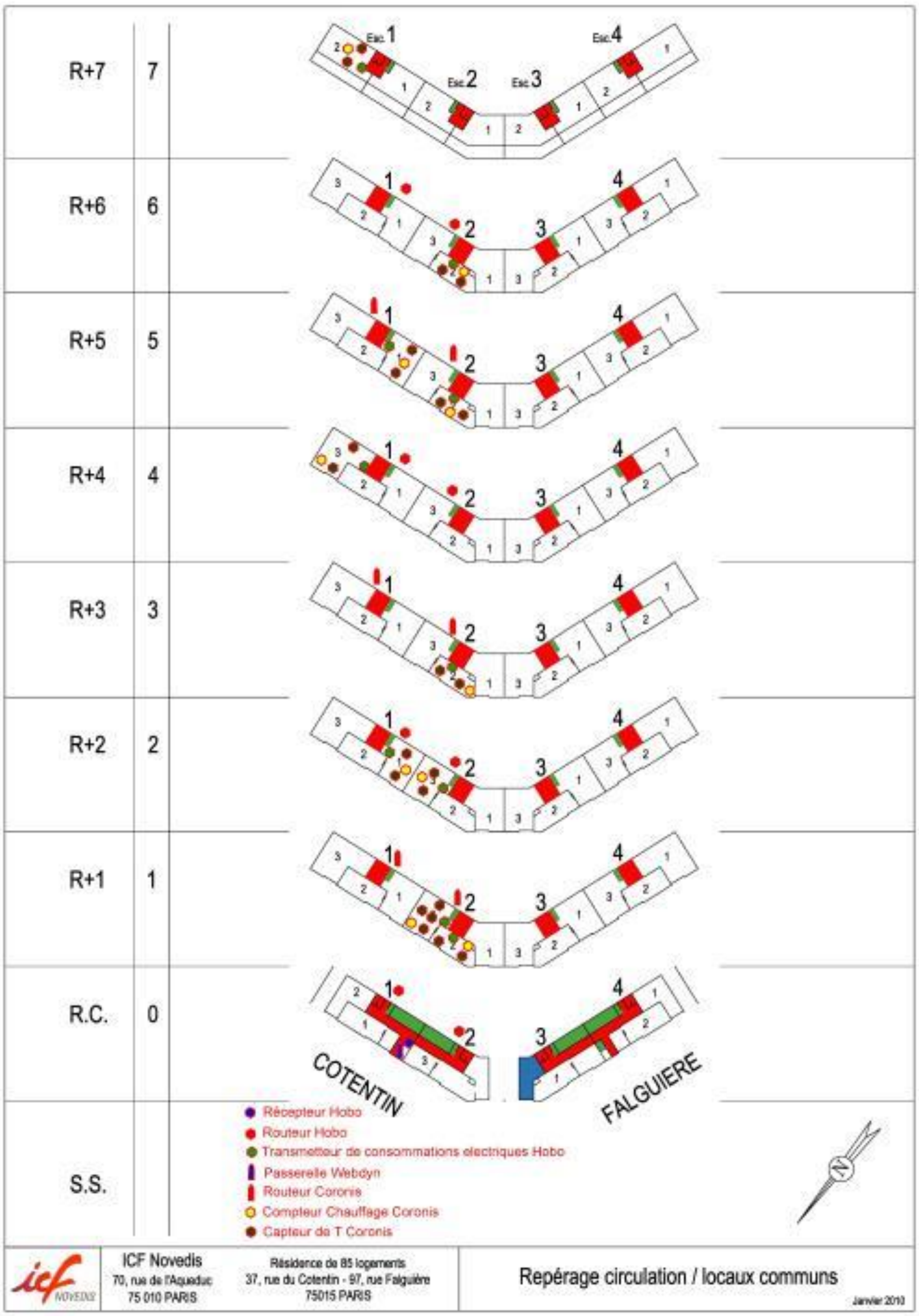
Dwelling number	Number of occupants	Typology/ Surface (m^2)	Location (the building is located at the corner of 2 streets (2 addresses for one building)	Measurements baseline period							
				T/RH living room	T/RH bedroom south	T/RH bedroom north	Electrical consumption				
							General	Light 1	Light 2	Light general	DHW
101	1	T3 / 50	**37, rue du Cotentin**	X	X					X	X
102	1	T2 / 42		X	X		X	X	X		X
132	1	T2 / 40		X	X			X	X		X
153	3	T4 / 66		X	X		X	X	X		X
163	3	T4 / 66		X	X	X		X	X		X
172	3	T3 / 63		X	X		X	X	X		X
221	3	T3 / 53		X	X					X	X
262	2	T2 / 38		X	X		X	X	X		X
312	1	T2 / 38	**97, rue Falguière**	X	X			X	X		X
332	1	T2 / 37		X	X		X	X			X
343	1	T3 / 53		X		X		X	X		X
353	Unknown	T3 / 55		X	X	X	X			X	X
402	2	T3 / 51		X	X		X	X	X		X
423	2	T3 / 55		X		X	X			X	X
431	3	T4 / 66		X	X	X		X	X		X
442	1	T2 / 40		X	X		X			X	X
453	1	T3 / 55		X		X		X	X		X

Annex 2: Organization of the baseline monitoring deployment on Paris site

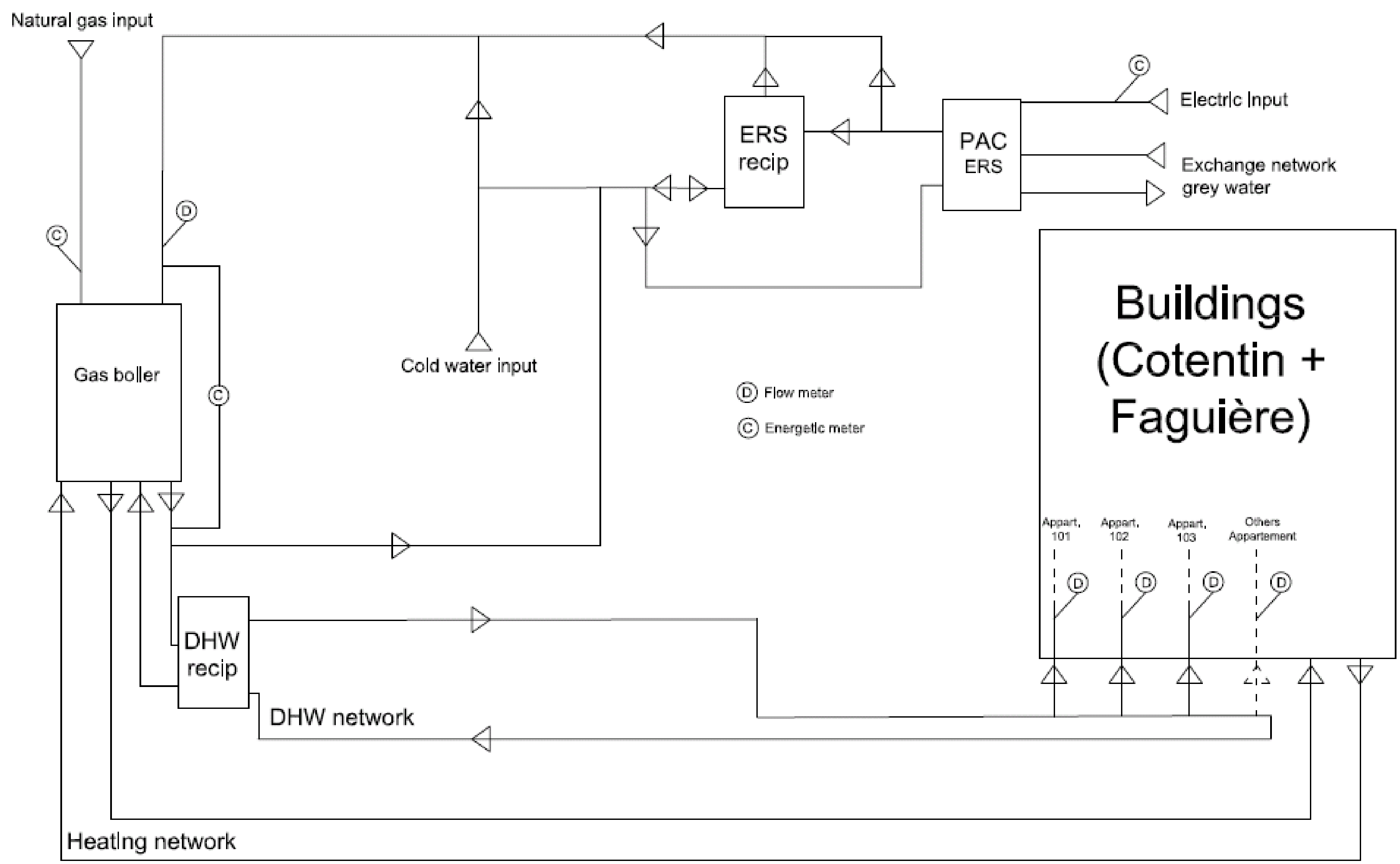


Organization of the baseline monitoring deployment on Paris site – The first column indicates the level in the building (RC=ground floor, R+1=1st floor, SS=basement etc…)

Annex 3: General infrastructure of monitoring system used after refurbishment on Paris site



Annex 4: Outline schematic of DHW production in the French site



Annex 5: Results of acoustic tests performed in Paris site after refurbishment

Différence de niveaux standardisée selon ISO 140-4

Mesurages in-situ d'isolement au bruit aérien entre pièces

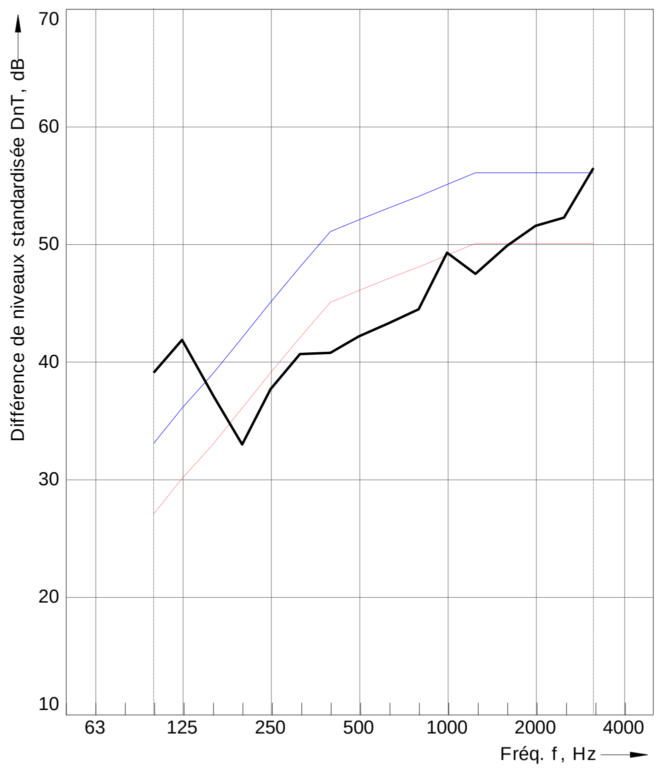
Client: Date d'essai: 10/09/2014

Description et identification de la construction et du montage de l'essai, direction du mesurage:

Volume de la pièce d'émission: 34.80 m³
Volume de la pièce de réception: 25,10 m³

Gamme de fréquence selon la courbe des valeurs de référence (ISO 717-1)

Fréq. f Hz	DnT 1/3 Octave dB
50	
63	
80	
100	39,0
125	41,8
160	37,0
200	32,9
250	37,6
315	40,6
400	40,7
500	42,1
630	43,2
800	44,4
1000	49,2
1250	47,4
1600	49,8
2000	51,5
2500	52,2
3150	56,4
4000	
5000	



Evaluation selon ISO 717-1

$D_{nT,w}(C;C_{tr})$ = 46 (0; -3) dB $C_{50-3150}$ =N/AdB; $C_{50-5000}$ =N/AdB; $C_{100-5000}$ =N/AdB;

Evaluation basée sur des mesures in-situ en bandes de tiers d'octave par méthode d'expertise $C_{tr,50-3150}$ =N/AdB; $C_{tr,50-5000}$ =N/AdB; $C_{tr,100-5000}$ =N/AdB;

Numéro du rapport d'essai: Nom de l'organisme responsable de l'essai: NOBATEK

Date: 15/09/2014 Signature: